Socio-Economic Demand Forecast Study

Supporting a National Plan to Transform the U.S. Air Transportation and Air Traffic Control Systems

Presented to the Air Transportation System Joint Planning Office

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Preface

Congress established the Commission on the Future of the United States Aerospace Industry in 2001 to study the U.S. aerospace industry and to assess its importance to the U.S. economy and national security. In its report to Congress one year later, the Commission issued a stern warning that the nation "stands dangerously close to squandering the advantage bequeathed us by prior generations of aerospace leaders." It also issued nine recommendations deemed essential to preserving U.S. global aerospace leadership in the 21st century. Key among them was a call for *"transformation of the U.S. air transportation system as a national priority."* [1]

In response to that recommendation, Secretary of Transportation Norman Mineta in 2003 established the *Next Generation Air Transportation System Joint Planning Office (ATS-JPO)* to develop and implement a long-term national plan that establishes goals, priorities, and strategies to transform the U.S. air transportation system to meet 21st century needs. [2] On November 25, 2003, the Secretary asked the President to adopt as a national priority the *Next Generation Air Transportation System Initiative.* [3] The initiative "would seek to transform the Nation's air transportation system to ensure that it can accommodate future demands while more effectively integrating security measures imposed since the 9/11 attacks into the system."

This report supports the Secretary's proposed initiative with the results of a year-long study that quantifies the benefits of a 21st century air transportation system capable of meeting projected demand in 2015 and 2025. The Socio-Economic Demand Forecast (SEDF) study thus establishes a firm foundation for what must follow—a complete cost-benefit analysis of potential federal investment in the Next Generation Air Transportation Initiative.[4] Completed in December 2003, the SEDF study also supports ATS-JPO efforts to develop a national plan that will define the proposed new national initiative.

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[1] Final Report of the Commission on the Future of the United States Aerospace Industry, pg 2-1.

[2] "MEMORANDUM OF UNDERSTANDING/AGREEMENT BETWEEN THE DEPARTMENT OF TRANSPORTATION (DOT), DEPARTMENT OF COMMERCE (DOC), DEPARTMENT OF DEFENSE (DOD), DEPARTMENT OF HOMELAND SECURITY (DHS), AND NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), for the Air Transportation System Joint Planning and Development Office (ATS-JPDO)," (draft, undated, unsigned). The ATS-JPO "will satisfy the U.S. Government's fundamental civil and national security requirements for creating and carrying out an integrated plan for a Next Generation Air Transportation System (NGATS) by recommending research and development on that system; creating an ATS Integrated Transition Plan (ITP) for the implementation of that system; coordinating aviation and aeronautics research programs …; coordinating goals and priorities and…research activities within the Federal Government with United States aviation and aeronautical firms; coordinating the development of new technologies …facilitating the transfer of technology ..to other Federal agencies…and the private sector; reviewing activities related to noise, emissions, fuel consumption, and safety conducted by Federal agencies…"

[3] Secretary of Transportation's letter to the President of the United States, November 25, 2003.

[4] The SEDF study does not address how and when to fund necessary research and technology development, the costs of implementing improvements to the air transportation system, or how such changes would be funded.

Executive Summary

The U.S. aeronautics industry remains one of the undisputed success stories in global competitiveness throughout the latter half of this century and is currently one of the largest positive industrial contributors to the U.S. balance of trade. Yet experts agree that demand for air transportation will soon outpace National Airspace System (NAS) capacity, and that such capacity shortfalls will impose significant, tangible costs to the nation. Long-term strategic planning is therefore essential to preserve U.S. global leadership in the 21st century and safeguard America's economic prosperity, national security, and quality of life. Such planning requires a broad-based national perspective that considers the needs of users and consumers and equips policy makers and planners with the information necessary to effect change.

In response to that need, the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) with GRA, Inc, the Logistics Management Institute (LMI), and the Volpe National Transportation Systems Center undertook a year-long study to assess the potential benefits of transforming the air transportation system to meet future demand. The SEDF study quantifies the projected economic loss to the United States over the period 2015-2025 should NAS capacity fail to keep pace with anticipated growth in demand. The study thus establishes a firm foundation for what must follow—a complete cost-benefit analysis of potential federal investment in a new national initiative to transform the air transportation system. The SEDF study estimates that the anticipated shortfall in NAS capacity could have significant costs for the nation, ranging between $91.6 billion and $229.4 billion from 2015-2025. [5]

OVERVIEW

Background

The SEDF study supports the ATS-JPO efforts to develop a long-term national plan to transform the U.S. air transportation system to meet 21st century demands.

Purpose of the Study

The purpose of the study was to improve understanding among policymakers and planners, segments of the aviation industry, and the public concerning the economic, safety, security, and quality-of-life impacts of the U.S. air transportation system on the nation. It was also to provide a clear and credible case for federal investment in the *Next Generation Air Transportation System Initiative*.

Study Elements

The study consisted of a literature survey, a model of future needs for aviation system capacity, and a demand-capacity analysis. The SEDF study team used these elements to accomplish the following:

- Identify socio-economic factors driving the air transportation system
- Quantify the value of the air transportation system to the U.S. economy today
- Forecast the demand for air travel that the U.S. air transportation system will need to accommodate in the future

[5] All values are in constant, undiscounted year 2002 dollars.

- Estimate the cost to the U.S. economy of a shortfall between the demand and supply of NAS capacity should the federal government fail to enhance the aviation system beyond the capacity and efficiency improvements called for in the Operational Evolution Plan (OEP), an FAA framework for capacity and efficiency improvements through 2015.

Scope

The SEDF study quantifies the economic cost of a projected NAS capacity shortfall in 2015 and 2025. The study considers commercial carrier and general aviation (GA) passenger flights only.

The study does *not* address:

- Cargo operations
- Military operations
- How and when to fund the needed research and development to improve the air transportation system to meet future demand

CHAPTER 1. KEY STUDY RESULTS

This SEDF study indicates that growth in demand for air transportation services will outpace NAS capacity by 2015, despite full implementation of the FAA OEP. Chapter 1 presents an estimate of the size of the NAS capacity shortfall and associated economic consequences. The estimate is presented in relation to the following NAS performance metrics:

- Growth in demand
- Losses and costs to passengers
- Cost of incremental delay
- Costs to airlines from increased delay

The SEDF study team estimated the economic cost of future NAS capacity constraints for three possible paths of future growth in demand for passenger air transportation.

- The **baseline forecast** assumes no radical changes in industry structure, a continuation of many recent trends (for example, increasing low fare carrier market share, increased use of regional jets), and is consistent with other assumptions embedded in the FAA's long-range forecast.
- The **high-end alternative forecast** assumes a more vigorous future than the baseline future where growth in air transportation demand exceeds the FAA long-range forecast.
- The **low-end alternative forecast** assumes a less optimistic future than the baseline future where constraints restrict growth in air transportation demand below the FAA long-range forecast.

GROWTH IN DEMAND

The SEDF study indicates that demand for domestic and international air transportation will grow between 2.0 and 2.5 times the levels seen in 2000.[6]

ESTIMATED LOSSES AND COSTS TO PASSENGERS IN 2015 AND 2025

The **baseline forecast** (based on FAA forecasts and forecast methodologies) analysis indicates that failure to expand NAS capacity to meet future demand could cost consumers $19.6 billion in 2025, up from an estimated $6.5 billion in 2015. Losses would increase progressively over the years, with an estimated cumulative impact of $143.6 billion over the period 2015-2025.

If demand follows the **high-end alternative forecast**, failure to expand NAS capacity to meet future demand could cost passengers $26.2 billion in 2025, up from an estimated $8.4 billion in 2015. The high-end demand forecast indicates that a NAS capacity shortfall could cost the nation $229.4 billion over the period 2015-2025.

If demand follows the **low-end alternative forecast**, failure to expand NAS capacity to meet future demand could cost $12.7 billion in 2025, up from an estimated $3.7 billion in 2015. The low-end demand forecast indicates a NAS capacity shortfall could cost the nation $91.6 billion over the period 2015-2025.

Figure 1 shows the details of the estimated losses and costs to passengers.[8] The baseline scenario indicates that airlines could incur $3.06 billion in additional operating costs in 2015 and $5.82 billion in 2025. The SEDF analysis assumes that these costs are recovered from passengers through higher fares and are thus accounted for in the estimated losses of consumer surplus.

Figure 1. Lost Value to National Economy in 2015 and 2025 from Capacity Constraints and Resultant Reductions in Flights (in $2002 Billions)

	Low-End Alternative Forecast		Baseline Forecast		High-End Alternative Forecast	
	2015	2025	2015	2025	2015	2025
Loss of consumer surplus in domestic air travel market	$1.74	$8.04	$3.30	$13.14	$4.78	$19.40
Loss of consumer surplus in international air travel market	$0.01	$0.18	$0.25	$0.80	$0.28	$0.95
Value of GA passenger miles lost	$0.03	$0.10	$0.07	$0.18	$0.09	$0.27
Cost of incremental passenger delay experienced	$1.91	$4.42	$2.91	$5.52	$3.29	$5.58
Total Annual Loss	**$3.69 billion**	**$12.7 billion**	**$6.53 billion**	**$19.6 billion**	**$8.44 billion**	**$26.2 billion**

This figure shows a range of projected economic costs to the national economy in 2015 and 2025 should future demand for air transportation services exceed available capacity. All forecasts (baseline, higher alternative, and lower alternative) assume no improvements to the air transportation system beyond those identified in the FAA's OEP. All values represent constant, undiscounted year 2002 dollars.

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[6] The study team selected 2000 as the reference year because it was prior to the drop in demand that followed the economic slowdown of 2001 and the September 11 attacks.

[8] When demand outstrips capacity, airlines will eliminate flights, and competition for remaining seats will drive up fares, pricing some passengers out of the market. The losses associated with those passengers who are priced out of the market and with those who will continue to fly while paying higher fares is measured as the loss in **consumer surplus**.

CHAPTER 2. NATIONAL VALUE OF AIR TRANSPORTATION

The national value of the U.S. air transportation systems derives from the degree to which it influences the quality of life and economic prosperity of the nation and its people. "Chapter 2. National Value of Air Transportation" presents a two-part examination of the social and economic impacts of the air transportation system on the nation today and potential impacts on its future evolution.

"Part 1. Social Value of Air Transportation" examines the impact of the air transportation system on the nation's quality of life today. Discussion also extends to key quality of life concerns and the role that federal investment in research and technology development will play to either help or hinder transformation of the air transportation system

"Part 2. Economic Value of Air Transportation" examines the economic impact of air transportation and related industries on the U.S. economy and illustrates the size and scope of the air transportation industry relative to the national economy. The section concludes with a detailed description of the SEDF study team's approach to estimating the economic value to passengers of transforming the air transportation system.

PART 1. SOCIAL VALUE OF AIR TRANSPORTATION

The U.S. air transportation industry contributes to business, personal, and family life across the nation in countless ways, every day. Whether it's moving people and goods father and faster in a global economy, enhancing public safety, maintaining national security, protecting the environment, or enabling travel to and from the United States for business and pleasure, the nation's air transportation enhances and extends the nation's quality of life.

Enhancing Quality of Life Today

- *Competing in a global economy.* Air transportation also allows business and industry to respond faster and more effectively to market demand, to reach new markets around the globe, obtain the best prices, and participate in just-in-time delivery to reduce manufacturer and business inventory costs. The U.S. Postal Service and others can deliver goods and mail faster and more efficiently with air transportation than with any other mode of transportation, thus enabling ecommerce. Because of the U.S. air transportation system and aviation-enabled precision agriculture techniques, farmers can cut costs, save time, and ensure that the entire agricultural operation is more efficient. Farmers can also ship agricultural products and other perishables while still fresh, and the nation can access a greater variety of fresh produce from U.S. and international markets year round. And aviation manufacturing is a consistent net exporter, adding tens of billions of dollars annually to the nation's balance of trade.

- *Maintaining national security.* Because of the U.S. air transportation system, the nation can defend its people and project power when and wherever necessary. The nation relies on the U.S. air transportation system and other aerospace capabilities to patrol the skies, and transport troops and government officials during periods of heightened security and actual threat. Defense aviation drives the research, development, and implementation of the world's most advanced technology to provide unparalleled protection for the U.S. and other nations in times of need.

- *Enhancing public health and safety.* Because of the U.S. air transportation system, firefighters and other first responders can react faster and more effectively to wildfires, earthquakes, and other disasters. Firefighters can map hundreds of miles and communicate location data to the field in near-real time using aviation-based wildfire mapping. Paramedics, physicians, and critical care nurses can transport donor organs and critically ill and injured patients via air ambulances and mobile intensive care units to hospitals, cutting critical minutes off transport time. Local, state, and federal law enforcement can monitor drug traffic and other illegal activity in border regions more effectively, covering thousands of miles with fewer workers.

- *Protecting the environment.* Because of the U.S. air transportation system, state and federal departments of fish and game and other environmental organizations can monitor, manage, and protect natural resources and public lands more effectively. Using aircraft to cover millions of square miles annually, environmental organizations can balance the needs of local communities with the ability of ecosystems to support soil, water, forests, wildlife, fish, and recreational resources.

- *Traveling within, to, and from the U.S.* Because of the U.S. air transportation system, travelers can traverse thousands of miles in hours instead of days to attend business, social, educational, and family functions.

These and other capabilities in the future will ensure that the safety and security of the air transportation system continues to improve along with increases in demand.

Enabling Air Transportation Tomorrow: Safety, Security, and Environmental Compatibility First

The U.S. economy depends on a robust air transportation system and stands to lose billions annually if future capacity fails to keep pace with anticipated demand. A national program to transform the system is therefore essential to preserve the nation's economic prosperity.

However, such a transformation depends on keeping safety, security, and environmental concerns essential first priorities. A public that lacks confidence in any aspect of air transportation will either stay home or seek an alternative mode of travel and in any case will avoid flying.

Long-term, high-payoff aerospace technologies must, therefore, not only aim to preserve U.S. global aerospace leadership in the 21st century and safeguard America's economic prosperity. They must also seek to improve quality of life by improving and protecting the environment, increasing mobility and safety, and ensuring the continued national security of the nation and its people.

- *Increasing Safety.* Pilots, controllers, dispatchers, and service technicians must enhance public health and safety by working to eliminate aviation-related deaths and injuries, while government, industry, and academia work to provide the necessary tools. Future research in enhanced vehicle system technologies may reduce the wake created by large aircraft, solving a safety problem that has plagued the industry. Such changes could lead to new designs with shorter take-off and landings, which, in some cases, could enable a complementary benefit of greater access at more locations and airports.

- *Ensuring Continued National Security*. Advances in biometric technologies could improve the effectiveness of passenger screening. Biometric systems measure an individual's unique physical or behavioral characteristics to verify identity. Common biometric systems used in security today include fingerprints, hand and finger geometry, facial recognition, and iris or retinal scanning. The ability to know the location of any aircraft at any time and to monitor unexpected deviations from the flight path could provide an early warning of a security threat. Surreptitious emergency transmissions from such aircraft, or the ability to deny flight control to unauthorized passengers, could mitigate such incidents. Such capabilities could help ensure that the safety and security of the air transportation system continues to improve along with increases in demand.

- *Enhancing Environmental Compatibility*. New aircraft engines, materials, and aerodynamic designs must change the effect air transportation has on the environment and local communities. Manufacturers must build aircraft that are quiet enough to eliminate local noise concerns and remove limitations on flights in key metropolitan areas. Aircraft and airports must also make significant reductions in emissions or risk possible new air transportation taxes, landing fees, or legislative action to limit operations.

Enabling Transformation with Revolutionary Technologies [9]

Advances derived from the fusion of biotechnology, nanotechnology, and information technology could enable revolutionary changes in aircraft, providing orders of magnitude increases in safety and reliability while vastly lowering operating costs. On board intelligence will be able to monitor aircraft health and predict the need for maintenance before problems occur, and in time, aircraft could even have the ability to self-repair. Revolutionary new nanotechnology composites could enable the construction of aircraft that are 100 times stronger than steel but weigh half as much as conventional aircraft, which could result in fuel savings of 25% and dramatically increase safety. New computational tools will allow fully integrated vehicle engine design, integrated health management, and management of the total vehicle air flow inside the engine and outside the aircraft. New integrated propulsion and vehicle technology advancements could optimize subsonic flight regimes, with twice the thrust to weight ratios, and enable sustained supersonic flight with minimal impact due to sonic booms or other environmental concerns for both civilian and military applications.

These and other technology advances will preserve and enhance the nation's quality of life while enabling the essential expansion of NAS capacity.

PART 2. ECONOMIC VALUE OF AIR TRANSPORTATION

The U.S. economy is comprised of business and industry sectors that depend on the nation's air transportation infrastructure to compete domestically and internationally. For many sectors, the nation's air transportation system is integral to their survival. Manufacturing, agriculture, international trade, travel and tourism, and many other industries and sectors rely on the air transportation system. Key economic contributions of the U.S. air transportation industry can be summarized as:

- Growth in U.S. gross domestic product (GDP) corresponds closely to growth in the air transportation industry, reflecting the derived nature of transportation demand in general. Since 1960, the rate of growth for revenue passenger miles (RPMs) equaled or exceeded that for GDP.
- The air transportation industry makes up approximately 1% of the total U.S. GDP. Gross output for the air transportation industry, which includes air transport in intermediate rather than final uses, is also approximately 1% of the total output of all industries in the U.S. economy.
- The air transportation industry is deeply enmeshed in the nation's economic structure and supply chain, delivering a wide variety of goods and services to industries and sectors that add value and sell downstream.
- Five commodity categories rely on air transportation for more than 80% of their overall transportation needs. The commodities are: 1) electronic components, 2) computer/office equipment, 3) aircraft and parts, 4) forestry/fishery products, and 5) scientific/controlling instruments. Three industry groupings spend more than half of their transportation dollars

[9] Aeronautics Vision for the 21st Century, NASA White Paper, March 5, 2001, www.ewh.ieee.org/soc/aes/Blueprint.doc

on air transportation: 1) computer/office equipment; 2) agriculture, forestry, and fishery services; and 3) aircraft and parts.

- Air transportation accounted for approximately one-fourth of all travel and tourism sales in 2002. The majority of international tourists arrive via air, bringing more than $60 billion in tourism revenues to America. Air transportation accounts for 24.4% of tourism related sales ($170 billion out of $709.8 billion in 2002)—second only to hotels and lodging at 27.9%, followed by restaurants at 18.5%.
- The use of air travel over automobile, bus, or rail increases with trip length. Air travel accounts for nearly 75% of round trips of 2000 or more miles in length. Global data show that as a nation's per capita GDP increases, its people have more discretionary income and shift their travel preferences from automobile, bus, and conventional rail to air and high-speed rail. Even for well-developed countries such as the United States, demand for high speed, affordable transportation, and timely delivery of goods and services increases with per capita GDP increases.
- Spending by international visitors to the United States contribute positively to the U.S. trade balance while the expenditures of U.S. travelers overseas detract from it. Overall, the U.S. had a positive trade balance of approximately $7.5 billion in 2002 from travel.
- Goods shipped by air (imports and exports) accounted for $468 billion in 2002, or 39% of the value of all imports and exports, even though goods shipped by air make up a very small portion of total imports and exports by weight.
- Air transportation accounts for a negligible amount of the *weight* of goods shipped in the U.S. but accounts for 3.3% of the *value* of all good shipped in the U.S.[10] Shipments weighing less than 50 pounds account for more than 30% of the value of goods shipped by air. Thus, small, expensive items such as jewelry, audio/video/communication equipment, and other high value products typically ship by air.
- Air transportation plays a larger role in international trade than in domestic trade. In part, this reflects the greater distance that imports and exports must travel, and in part, it reflects the types of goods shipped. Air accounts for a negligible percentage of total shipments by weight. However, it accounts for 30-50% of merchandise imports and exports by value. Clearly, air is the preferred mode of shipment for high valued goods. Electrical machinery and data processing equipment account for the largest groups by value of imported goods that ship by air. Diamonds and jewelry, fresh flowers, organic chemicals, and medical or surgical instruments also account for large shares of U.S. imports shipped by air.
- Employment in the air transportation service industry totaled 873,084 in 1997 (excluding air transportation manufacturing). Large certificated air carriers employ the largest number of workers, followed by airport operations, support activities, and other air transportation activities. This does not include employment in private aviation and industries that supply the air transportation industry or FAA employees that modernize, operate, and maintain the air traffic control system.
- Airport economic activity is an important part of the air transportation industry's impact within the U.S. economy, accounting for about $14.5 billion in revenues and $11 billion in expenses.

Economic Cost of the Shortfall

Failure to transform the air transportation system in time to meet anticipated future demand increases will make it increasingly difficult for air transportation to continue to play this positive role

[10] The actual total value of goods shipped by air may exceed 3.3%, because the 1997 Commodity Flow Survey (CFS} does not break out air transportation within the "parcel/postal/courier" category, which is almost three times the value of air transportation.

within the overall economy. A growing shortfall between the demand for air transportation and air system capacity will lead to corresponding increases in "embedded"[11] delay and other system inefficiencies, and a cascading series of tangible impacts on airlines and passengers:

- Airline operating costs will rise.
- Average fares will rise. Those who rely on affordable air transportation may be priced out of the market, and those who continue to fly will pay more with less money left for other expenditures.
- Travelers will be forced to travel during less desirable times, to, and from less desirable locations due to insufficient air service.
- Transportation and shipping costs will rise for those sectors of the economy that are dependent upon air transportation.
- Other industries and sectors of the economy will absorb much of the cost and may become less competitive in global markets.

CHAPTER 3. FUTURES AND FORECASTS

This chapter discusses the modeling of future NAS capacity, air travel demand forecast, and the economic loss expected to result from a capacity shortfall in 2015 and 2025. The SEDF analysis shows that without further investment in infrastructure improvements, procedural and policy changes, and technology research and development, demand growth will outpace NAS capacity and significantly degrade the quality and quantity of service. The SEDF study presents this performance degradation in terms of the lost economic value to the nation due to the projected shortfall between capacity and demand.

METHODOLOGY OVERVIEW

The study team used the following process to generate the economic valuation:

- Generated baseline and alternative demand forecasts (RPMs) for 2015 and 2025.
- Developed future flight schedules assuming the same business models from flight schedules in 2000.
- Estimated the increase in NAS capacity due to planned modernization efforts, based primarily on the OEP. Assumed implementation prior to 2015 and no improvements after 2015.
- Incorporated information into LMINET[12] model of 102 busiest airports, modeled future operations given forecast demand and system capacity levels, and eliminated flights that exceeded imposed delay tolerance.[13] For busiest of 102 airports, delay tolerance was set at peak quarter-hourly delay experienced at that airport in the year 2000. For less congested airports, the methodology allowed delays to grow no greater than the good weather average delays at the 31 large hub airports in 2000.
- Calculated RPM loss due to eliminated flights, where RPM loss represents unsatisfied demand.

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[11] Embedded delay is delay that airlines routinely build into their schedules to accommodate known expected delays or to avoid a report of an unscheduled delay in the DOT's *On-Time Performance Report*.

[12] LMINET is a queuing network model of the entire NAS developed by LMI for NASA.

[13] Average delay in 2025 would be 150 minutes if flights are not eliminated. This is the reason that the SEDF analysis focused on eliminating flights as the likely response to a capacity shortfall in future years.

- Applied demand elasticity values to determine the resultant yield/price increases associated with the unsatisfied demand (reduced supply due to system capacity constraints).

- Calculated dollar figure for consumer loss created by shift in supply curves due to system capacity constraints and associated yield/price increase. Resultant range of consumer loss derived from 1) different elasticity values applied to domestic market and 2) different demand forecasts for each of three alternatives.

The study team relied on FAA forecasts and forecast methodologies for projecting demand for domestic and international air travel. This demand is stated in terms of annual RPMs flown by commercial air carriers and GA system users. Inputs included GDP forecasts, air carrier yield forecasts (revenue of air carriers), OMB GDP forecasts, and air carrier yields from projected trends.

Projections of future overall air travel demand were then used as inputs for an LMI model, which 1) distributed overall revenue passenger seat miles to the amount of travel between individual origin-destination pairs, 2) assigned aircraft to carry the passengers, and 3) projected the number and schedule of aircraft flights between origin-destination pairs. These flight assignments were based on current air carrier operating practices.

Current NAS capacity and planned OEP enhancements were examined to assess how many flights could be handled under these conditions. Analysis using LMI models was conducted to estimate the amount of demand that could be handled by the current infrastructure and planned enhancements. No further increase in capacity was assumed beyond implementation of the OEP in 2015.

Both unconstrained demand (in which demand is unconstrained by any capacity limitations to handle the demand), and constrained demand (in which the number of flights is limited by the projected capacity to handle flights) are estimated. The unconstrained demand is compared to that constrained by current planned capacity.

LOSS DUE TO CAPACITY SHORTFALLS

The SEDF study quantified the potential economic cost of a NAS capacity shortfall by 1) eliminating flights from the flight schedule (which the study team assumed as the likely response to the capacity shortfall in future years), 2) converting the lost flights to lost RPMs, and 3) estimating a value of the foregone flights as lost economic consumer surplus[15.]

Figure 2 shows recent and projected demand for RPMs. Under the assumptions used regarding aircraft size, load factor, and other parameters, 41,265 daily domestic flights would be required in 2015 to fulfill that year’s annual demand for 780.8 billion domestic RPMs. However, the system will be unable to accommodate 2,610 of these daily domestic flights, due to capacity constraints. These 2,610 foregone daily flights represent 99 million foregone daily domestic RPMs. Comparable estimates were also made for international and GA flights and RPMs that would be lost because of capacity constraints.

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[15] Buyers able to pay the market clearing price for air transportation—but who are also willing to pay more, if necessary— enjoy a kind of “bonus,” since they acquire the service for less than they are willing to pay. This bonus, aggregated over all consumers able to purchase air transportation services at a lower price than they are willing to pay is termed “consumer surplus.” The SEDF study estimates (among other factors) the amount of consumer surplus that will be lost if NAS capacity fails to keep pace with future demand and average yields rise to higher levels.

Figure 2. Actual and Forecast Unconstrained Demand (Shows actual number of annual RPMs demanded in 2000 and projections for 2015 and 2025.)			
	Year 2000	Year 2015	Year 2025
Domestic (billions of RPMs)	512.3	780.8	1,116.3
International (billions of RPMs)	181.8	293.3	446.6
General aviation (billions of passenger miles)	13.9	20.8	29.8

Figure 3 presents baseline estimates of the economic costs that could occur without action to provide increased NAS capacity beyond improvements called for in the OEP.

The SEDF study results indicate that the loss to consumers from capacity constraints is $6.53 billion in 2015 and becomes progressively larger, reaching $19.6 billion in 2025 as demand increases and capacity grows little beyond 2015 levels.

Figure 3. Baseline Forecast Results		
Future NAS Performance and Shortfall Metrics	2015	2025
Lost value from foregone flights for domestic air travel (domestic consumer surplus)	$3.30	$13.14
Lost value from foregone flights for international air travel (international consumer surplus)	$0.25	$0.80
Lost value from foregone flights for general aviation	$0.07	$0.18
Additional cost to passengers due to increased delays	$2.91	$5.52
Total annual loss	$6.53 billion	**$19.6 billion**

SENSITIVITY ANALYSIS OF FUTURE AIR TRAVEL AND SHORTFALL

The SEDF study team also conducted a sensitivity analysis, based on a range of possible future demand levels around the baseline FAA-based forecast. The team estimated the high and low demand numbers by varying the assumed future growth rate for the nation's GDP and the rate of decline in air carrier yield (i.e., fare revenue per passenger seat mile flown).

Mean and standard deviation for, and correlation between, GDP and air carrier yield were calculated from historical data as measures of variability in real GDP and air carrier yield. Monte Carlo simulation was then used to obtain a range of possible revenue passenger mile projections for 2015 and 2025. The 10 percentile and 90 percentile values of revenue passenger mile projections were used as inputs to the LMI model to calculate the foregone flights and increased delays for future demand levels at these 10 percentile and 90 percentile values.

Figure 4 shows the results of the sensitivity analysis of the lost value that could result from failing to meet future demand under the low and high alternatives for demand. The largest source of variation in impacts is for consumer surplus losses associated with foregone trips and higher airfares. The impacts range from $3.69 billion to $8.44 billion in 2015 and from $12.7 billion to $26.2 billion in 2025.

Figure 4. Sensitivity of Lost Value (in $Billions)				
	Low-End Alternative Results		High-End Alternative Results	
Category	2015	2025	2015	2025
Lost value from foregone flights for domestic air travel (domestic consumer surplus)	$1.74	$8.04	$4.78	$19.40
Lost value from foregone flights for international air travel (international consumer surplus)	$0.01	$0.18	$0.28	$0.95
Lost value from foregone flights for general aviation	$0.03	$0.10	$0.09	$0.27
Additional cost to passengers due to increased delays	$1.91	$4.42	$3.29	$5.58
Total (Billions of 2002 Dollars)	**$3.69**	**$12.7**	**$8.44**	**$26.2**

Note: Table reflects impacts on consumers only (no air carrier impacts).

CHAPTER 4. OTHER ALTERNATIVE FUTURES

This chapter discusses possible future levels of air transportation demand and capacity, and identifies major factors that can help or hinder growth in future demand.

The future air transportation system may not necessarily correspond to the one implied by the variables used in the SEDF study. Other more indirect factors can influence future demand for air transportation services—e.g., environmental concerns, safety and security issues, future technological innovations, new air transportation systems and equipment, and new operational concepts and practices. Understanding these factors and their potential influences to enable or constrain demand can enable policymakers and planners to more broadly assess the requirements of the future air transportation system.

The potential influences of these variables on future air transportation demand can be assigned three value ranges: one that corresponds to the baseline forecast, one that suggests lower growth, and one that suggests higher growth. Depending on the values and emphasis assigned to each variable, it is possible to construct many different demand forecasts for 2015 and 2025. These variables fall into the following categories of influence on future air transportation demand:

- Those with a primary impact on GDP or population
- Those with a primary impact on yields and/or taxes
- Those with other primary impacts, such as the propensity to travel

CONCLUSIONS

Future U.S. economic prosperity and quality of life depend on an air transportation system that can accommodate future demand. Implementing the OEP will not be enough. Now is the time to begin designing the air transportation system of the future, which will require nothing less than complete transformation. Such an ambitious undertaking will require focused research and technology development and new public policy changes that systematically coordinate airport, aircraft, and air traffic control system technologies and procedures.

The SEDF study lays the foundation for transformation by quantifying the national economic cost of "business as usual." The study thus provides the foundation for additional studies that will consider both benefits and costs associated with a 21st century air transportation system as the national plan develops and additional information emerges.

Government must encourage industry, labor, and academic institutions to work together to support transformation of the air transportation system and reward them for collaborative efforts in research, product development, and engineering, and in delivering products and services that harness their unique strengths and skills.

A key question surrounding the cost of transformation concerns how to pay for it. The answer depends in part on fiscal requirements, whether funding will be available from the Airport and Airway Trust Fund, and if so, whether the amount will be sufficient. If funds are unavailable or insufficient, users or others may be required to contribute.

The need for additional funding could affect the SEDF results because it could affect current assumptions about the future price of flying.

Introduction

This introduction presents background information on how the Socio-Economic Demand Forecast (SEDF) study supports the efforts of the Air Transportation System Joint Planning Office (ATS-JPO) to develop a long-term national plan to transform the air transportation system. The introduction also presents a roadmap to this report.

This report presents the results of the year-long socio-economic and demand forecast study undertaken in support of the ATS-JPO effort to develop a long-term national plan to transform the air transportation system. The original ATS-JPO targeted five key areas:

- The future of the U.S. air transportation system
- Socio-economic demand forecast of the future system
- Developing goals, strategy and a policy to meet future needs
- Operational concept for transformation of the air transportation system
- Integrated research requirements for the transformation

The SEDF study examines the socio-economic drivers of air transportation demand and identifies the national value of air transportation. The study also presents forecasts of the anticipated level of air transportation demand and examines scenarios about the future supply of infrastructure to support that demand. Finally, the study analyzes the capacity of the air transportation infrastructure relative to anticipated demand through 2025 and estimates the economic costs of failing to accommodate future demand.

The SEDF study quantifies the future cost to the economy if NAS capacity fails to keep pace with demand growth. The study terms this level of demand growth as “unconstrained demand” in that it reflects the projected level of aviation activity that would occur given anticipated economic growth and trends in airline industry pricing. Constrained demand, on the other hand, is defined as equal to the level of capacity expected to result from known improvements to the air transportation system between now and year 2015 (including major portions of the FAA OEP and planned development and construction of new runways). The level of demand that can be accommodated in such a system is equal to the aircraft operations where performance (in terms of delay and congestion) is no worse than that observed in 2000, a year when the capacity of the air transportation system was seriously taxed to meet demand. The study assumes that no new capacity initiatives will be undertaken after 2015. The SEDF study looked at the differences between demand and constrained capacity and estimated the cost to the economy of a capacity shortfall in terms of the following measures:

- Increased delay cost to passengers and airlines
- Increased cost of transportation (fares) for passengers
- Reduced number of passenger trips due to insufficient NAS capacity

The air transportation system will fail to meet future demand without significant new investment in capacity and efficiency improvements that go beyond those called for in the OEP, the FAA framework for improvements through 2015. [16] In the absence of investment to continue improving the air transportation system after completion of the OEP, accommodating continued growth in demand after 2015 will become increasingly problematic. In the absence of further capacity enhancements, the system will become saturated, which may mean that additional flights would be unable to gain access to the system. Some passengers and air cargo will be unable to fly at preferred times or may find it unaffordable to fly. One objective of the SEDF study focused on assessing future levels of demand for air transportation services in order to quantify these potential losses, both in terms of disrupted air transportation activity and economic losses. Avoiding such losses represents the benefits of an air transportation system that can meet projected growth for system demand.

Air transportation provides a significant contribution to the national economy and closely links to the workings of many different economic sectors. Thus, a significant shortfall of system capacity will impose tangible costs to the nation—longer and more frequent flight delays, higher fares, and slower, less efficient transportation as passengers and cargo are diverted to alternative modes of travel. In sharp contrast, an air transportation system that can accommodate future demand will strengthen the nation and the economy. Meeting future demand will help to:

- Maintain and increase U.S. economic competitiveness by providing the foundation for a more efficient, higher capacity, and faster global air transportation system

- Enhance our national security by strengthening homeland defense while enabling our military to project power anywhere in the world at anytime

- Improve the quality of life of all Americans by enabling them to travel more easily, when and where they want

Now is the time to begin designing the transformed air transportation system of the future. Accomplishing this will require focused research and technology development and new public policy changes that systematically coordinate airport, aircraft, and air traffic control system technologies and procedures to allow more aircraft to operate in what in many cases are already seriously congested airports and airspace. The SEDF study is intended to help policy makers and planners, segments of the air transportation industry, and the public understand the benefits of such a system. This report focuses on the benefits of being able to accommodate the growth in future demand that will naturally accompany economic growth and transformation. Future studies can consider both the benefits and the costs of a future transformed air transportation system as additional information becomes available about possible strategies and technologies for meeting future needs.

SEDF ANALYSIS APPROACH

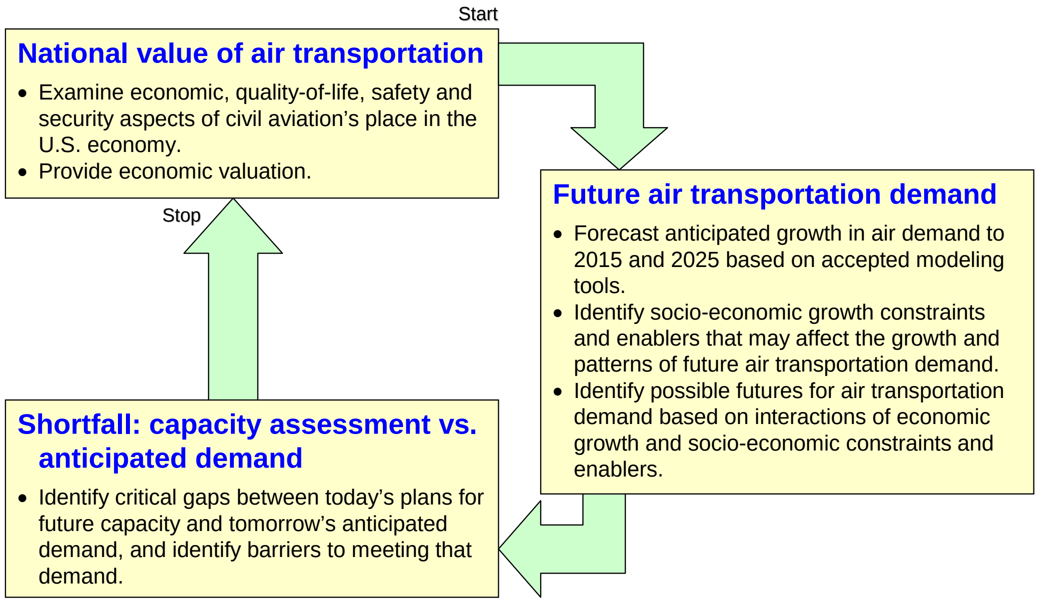
The SEDF study began by quantifying the national value of air transportation in terms of its role in the economy as well as how it influences that nation’s quality of life. The next step focused on projecting the anticipated growth in air transportation demand to 2015 and 2025 based on the FAA long-range aviation forecast. In addition, the SEDF team analyzed enablers and constraints that could affect the growth and the patterns of future air transportation demand. The study team reviewed possible futures for air transportation demand based on the interactions of economic growth and socio-economic constraints and enablers.

Finally, the SEDF team assessed future capacity levels in relation to anticipated demand. This was done by first estimating future demand for passenger air transportation services, assuming that there

[16] The *Final Report of the Commission on the Future of the United States Aerospace Industry* concluded that “The U.S. Air Transportation System: Does Not Meet Future Demand” and that “the current OEP does not give the nation sufficient capacity to meet long-term demand.” page 2-4.

would be no constraints on the ability to satisfy demand. Then the level of demand that the system would be able to handle if no further system improvements were undertaken after 2015 was estimated. Comparison of these estimates reveals that there is a considerable shortfall in capacity, which grows year-by-year from 2015 to 2025. Figure 5 illustrates the process.

Figure 5. SEDF Analysis Approach



SEDF Analysis Process and Components

The SEDF team performed the following activities in support of the analysis:

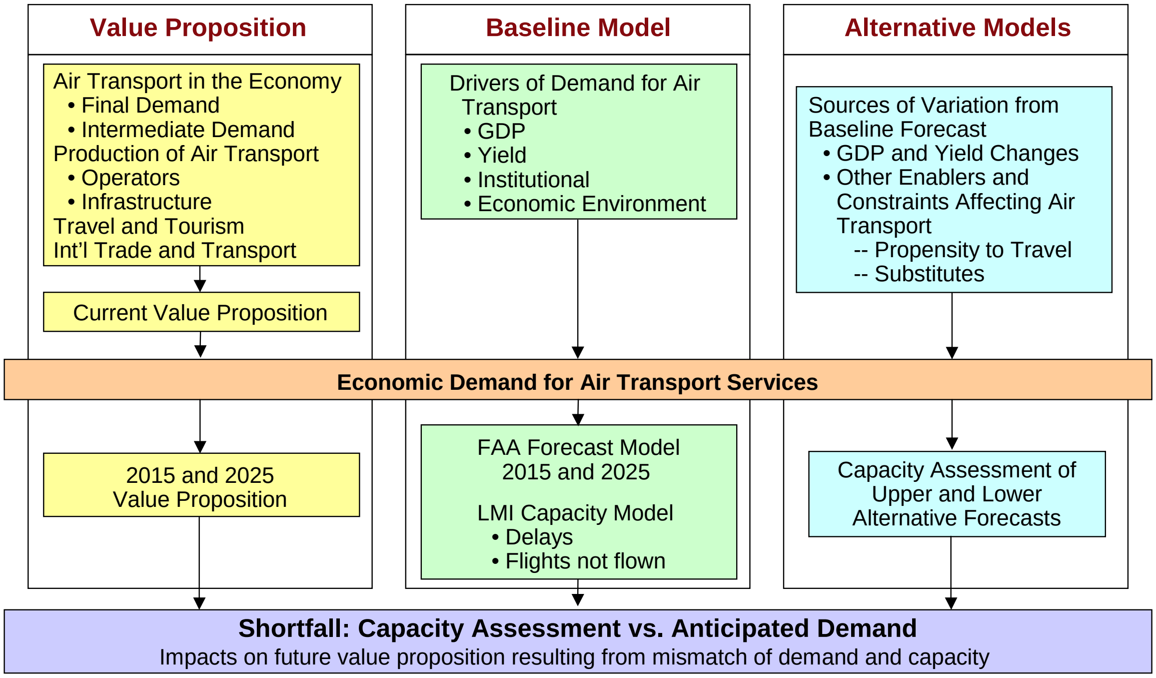
- The SEDF study team first stated a value proposition for today and the future based on how air transportation fits into the economy and how it supports travel and tourism, international trade, other transportation sectors, and related industries.

- Second, the team developed a baseline model of the air transportation system. The model considered both demand and supply in terms of a long-range forecast based on FAA aviation forecasting models and an LMI capacity model. The team used the models to assess the level of delays and flights not flown because of insufficient capacity.

- Finally, the study team considered alternatives to the baseline assessment. This allowed consideration of economic demand for air transportation services as well as an estimate of the economic cost of the shortfall when capacity could no longer meet projected levels of demand over a range of plausible futures.

Figure 6 identifies the major components of the SEDF analysis.

Figure 6. SEDF Analysis Components



REPORT ORGANIZATION

- **Introduction** discusses the SEDF background and approach and presents a roadmap to this report.

- **Chapter 1: Key Study Results** summarizes findings from the year-long SEDF study. The chapter presents the estimated economic loss to the nation in 2015 and 2025 in terms of lost (i.e., foregone) flights, RPMs, and the amount of delay and associated economic costs that could result from an anticipated shortfall in NAS capacity. The consolidated results presented in this chapter are presented for the reader's convenience and are discussed in detail in chapter 3.

- **Chapter 2: National Value of Air Transportation** considers both the social and economic value of transportation to the nation: why improving and protecting the environment while maintaining the safety and security of the air transportation system must remain essential first priorities in a national program initiative to transform the air transportation system. The chapter also considers how the air transportation industry fits into today's economy and supports national objectives, including economic growth.

- **Chapter 3: Futures and Forecasts** assesses the relationship between demand and capacity and quantifies the economic shortfall from a future where capacity is unable to meet projected levels of demand. This is done by estimating the increase in delays and the number of flights that cannot be accommodated in a future air transportation system unable to meet the levels of projected demand.

- **Chapter 4: Other Alternative Futures** reviews scenario-based planning studies and identifies additional factors that may influence future supply or demand.

- **Conclusion** summarizes implications of the analysis presented in this report and examines the rationale for governmental investment in the infrastructure necessary to increase capacity to meet the demand in the future air transportation system.

APPENDICES

The following appendices contain additional information relative to the SEDF analysis.

- APPENDIX A. Bibliography
- APPENDIX B. Key Assumptions
- APPENDIX C. Previous Scenario-Based Studies
- APPENDIX D. Embedded Delay Details
- APPENDIX E. Demand Forecast Literature Review
- APPENDIX F. Economic Impact Studies Literature Review
- APPENDIX G. Biographical Summaries

The SEDF team also prepared the following papers and presentations:

- Airline Economic and Business Models
- Aviation-Related Energy and Emissions
- Aviation-Related Security
- Aviation Security Detection Technologies for Weapons and Explosives
- Aviation Security and Biometric Technologies
- Summary of Trends and Projections from Recent Future Scenario Planning Exercises

Chapter 1. Key Study Results

This SEDF study indicates that growth in demand for air transportation services will outpace NAS capacity by 2015, despite full implementation of the FAA OEP, and that the loss to society from capacity constraints could reach $6.53 billion in 2015 and become progressively larger, reaching $19.6 billion in 2025 as demand increases and capacity grows little beyond 2015 levels.

This chapter highlights the baseline results according to the following NAS performance metrics:

- Growth In Demand
- Losses and Costs to Passengers
- Cost of Incremental Delay
- Costs to Airlines From Increased Delay

The chapter focuses on SEDF baseline results for 2015 and 2025. A summary of high- and low-end alternative SEDF results appears at the end of the chapter.

BASELINE RESULTS

The **baseline forecast** assumes no radical changes in industry structure and a continuation of many recent trends (e.g., increasing low fare carrier market share, increased use of regional jets) and is consistent with other assumptions embedded in the FAA long-range forecast.[17] The baseline forecast also assumes full implementation of the FAA OEP by 2015.

Growth in Demand

SEDF results indicate that demand in 2025 for domestic and international air transportation will grow to between 2.0 and 2.5 times the levels seen in 2000 and will grow faster than the general economy.[18] The baseline, high and low demand forecasts provide a range of domestic and international demand, as shown in Figure 1-1.

Figure 1-1. Estimated Demand Growth in 2015 and 2025

Possible Future	Demand (Billions of RPMs)			Multiplier (2025/2000)
	2000	2015	2025	
High-end alternative	694.1	1,144.3	1,743.0	2.51
Baseline	694.1	1,074.1	1,562.9	2.25
Low-end alternative	694.1	979.7	1,397.4	2.01

SEDF results further indicate that air carrier demand, as measured by domestic RPMs, could continue to grow faster than GDP.

- Forecasts for 2002 through 2014 indicate that domestic RPMs could increase at an annual average rate of 3.9%— higher than the 3.2% annual rate of growth assumed for real GDP.

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[17] FAA Aerospace Forecasts Fiscal years 2003-2014. US Department of Transportation, FAA, Office of Aviation Policy and Plans. March 2003.

[18] The study team selected 2000 as the reference year because it was prior to the drop in demand that followed the economic downturn in early 2001 and the September 11 attacks.

- Domestic RPMs could reach 1.116 trillion in 2025, up from 780.8 billion annually in 2015. Real yields would be 10.84 cents and 9.64 cents for 2015 and 2025, respectively.
- International RPMs could reach 293.3 billion and 446.6 billion, with real yields of 9.09 cents and 8.82 cents for 2015 and 2025, respectively

- Forecasts for 2014 through 2025 indicate that domestic RPMs could increase at an annual rate of 3.6%—higher than the rate of real GDP, which is projected to grow by 3.1% annually.
- International RPMs, which have historically grown at faster rates than domestic RPMs, are assumed to continue this historic relationship to forecast domestic RPMs.

Losses and Costs to Passengers

SEDF **baseline results** indicate that failure to expand NAS capacity to meet future demand will cost consumers $19.6 billion in 2025, up from an estimated $6.53 billion in 2015. Losses would increase progressively over the years, with an estimated cumulative impact of $143.6 billion over the period 2015-2025. See Figure 1-2.

Figure 1-2. Aggregate Passenger Impacts, 2015 – 2025 (in Constant 2002 $ Billion)

Demand Forecast	Impact 2015 – 2025
Baseline demand forecast	$143.6
High-end alternative forecast	$229.4
Low-end alternative forecast	$91.6

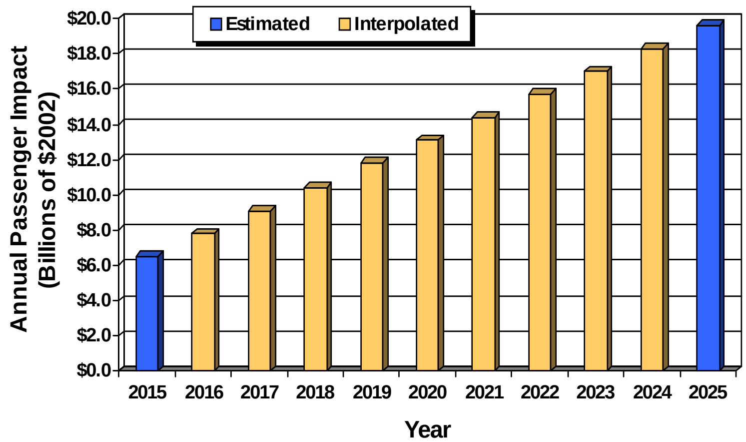
The loss in domestic and international consumer surplus will contribute heavily to the cost of a future NAS capacity shortfall, as shown in Figure 1-3. SEDF baseline results indicate that the annual loss for domestic and international commercial air transportation and GA (from lost consumer surplus) will reach $3.62 billion in 2015 and $14.1 billion in 2025.

Figure 1-3. Baseline Forecast Results (in $ Billion)

Future NAS Performance and Shortfall Metrics	2015	2025
Lost value from foregone flights for domestic air travel (domestic consumer surplus)	$3.30	$13.14
Lost value from foregone flights for international air travel (international consumer surplus)	$0.25	$0.80
Lost value from foregone flights for general aviation	$0.07	$0.18
Total annual lost consumer surplus	**$3.62 billion**	**$14.1 billion**
Additional cost to passengers due to increased delays	$2.91	$5.52
Total annual loss	$6.53 **billion**	**$19.6 billion**

Figure 1-4 shows the estimated and interpolated annual passenger impacts for the period 2015 to 2025. These impacts include lost consumer surplus and the cost to passengers due to increased delays.

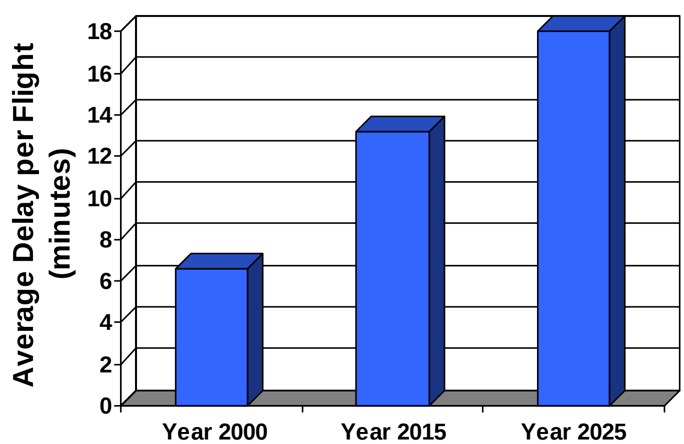
Figure 1-4. Annual Passenger Impacts, 2015 – 2025, Baseline Demand Forecast (Billions of Constant 2002 Dollars)



Cost of Incremental Delay

The SEDF baseline results indicate that average delays following implementation of the OEP by 2015 will still increase significantly—from about six minutes in 2000 to 18 minutes by 2025, as shown in Figure 1-5.

Figure 1- 5. Average Delay per Flight



Figures 1-6 and 1-7 report estimated annual delay impacts for 2015 and 2025, respectively, associated with the increase in delays as capacity constraints affect more and more airports.

Figure 1-6. Annual Economic Loss from Incremental Delay in 2015, Baseline Demand Forecast				
	All Aircraft	**Air Carrier**	**Commuter**	**General Aviation**
Incremental hours of delay	1,924,718	877,225	444,306	603,188
VOC ($ per hour)		3,043	608	199
Passenger delay cost ($ per hour)		2,932	645	83
Annual VOC ($ million)	3,060	2,669	270	120
Annual passenger delay ($ million)	2,908	2,572	286	50
Total	**$5,968 million**	**$5,241 million**	**$557 million**	**$170 million**

VOC: variable operating costs

Figure 1-7. Annual Economic Loss from Incremental Delay in 2025, Baseline Demand Forecast				
	All Aircraft	**Air Carrier**	**Commuter**	**General Aviation**
Incremental hours of delay	3,748,341	1,667,456	817,468	1,263,417
VOC ($ per hour)		3,043	608	199
Passenger delay cost ($ per hour)		2,932	645	83
Annual VOC ($ million)	5,823	5,074	497	251
Annual passenger delay ($ million)	5,520	4,888	527	105
Total	**$11,343 million**	**$9,962 million**	**$1,024 million**	**$356 million**

Costs to Airlines from Increased Delays

SEDF baseline results indicate that airlines also will face increased operating cost increases due to higher levels of delays. Figure 1-8 estimates delay costs to airlines, which range from $3.06 billion in 2015 to $5.8 billion in 2025. It is assumed that these costs will be passed to passengers as part of higher fares, and that these costs are therefore already counted in the passenger consumer surplus loss values.

Figure 1-8. Summary of Airline Impacts Estimated, Baseline Demand Forecast		
Category	**2015**	**2025**
Incremental variable operating costs incurred (billion)	$3.06	$5.82

HIGH-AND LOW-END ALTERNATIVE FORECAST RESULTS

The **high-end alternative forecast** indicates that failure to expand NAS capacity to meet future demand could cost consumers $26.2 billion in 2025, up from an estimated $8.44 billion in 2015, and that the cumulative impact of a capacity shortfall could reach $229.4 billion over the period 2015-2025. The high-end alternative forecast assumes a more vigorous future than the baseline forecast, where growth in air transportation demand exceeds the FAA long-range forecast

The **low-end alternative forecast** indicates that failure to expand NAS capacity to meet future demand could cost consumers $12.7 billion in 2025, up from an estimated $3.69 billion in 2015, and that the cumulative impact of capacity shortfall could reach $91.6 billion over the period 2015-2025. The low-end alternative forecast assumes less robust growth than the baseline forecast, where growth in air transportation demand is below the FAA long-range forecast.

Chapter 2. National Value of Air Transportation

The national value of the U.S. air transportation system derives from its contributions to the quality of life and economic prosperity of the United States and its people. This chapter of the SEDF report examines the social and economic contributions of the air transportation system today and its potential impact in the future. It also presents a methodology for assessing economic consequences that may occur if NAS capacity fails to keep pace with anticipated demand growth.

Chapter 2 consists of two major sections: “Part 1. Social Value of Air Transportation,” and “Part 2. Economic Value of Air Transportation.”

“Part 1. Social Value of Air Transportation” examines the impact of the air transportation system on the nation’s quality of life today. Discussion extends to key quality of life concerns and the role that federal investment in research and technology development will play to either help or hinder transformation of the air transportation system.

“Part 2. Economic Value of Air Transportation” examines common measures for assessing the potential economic consequences of allowing the air transportation system to lag behind growing demand for the services it provides. The section also quantifies the role of air transportation and related industries on the economy, by presenting data that illustrates the size of the industry and the breadth of its presence throughout the economy. The section concludes with a description of the SEDF methodology for estimating the economic impact of failing to transform the air transportation system to meet future demand—i.e., the cost to the nation of a NAS capacity shortfall in the future.

PART 1. SOCIAL VALUE OF AIR TRANSPORTATION [19]

ENHANCING QUALITY OF LIFE TODAY

The U.S. air transportation industry contributes to business, personal, and family life across the nation in countless ways, every day. Whether it’s moving people and goods farther and faster in a global economy, enhancing public safety, maintaining national security, protecting the environment, or enabling travel to and from the United States for business and pleasure, the nation’s air transportation enhances and extends the nation’s quality of life.

Competing in a Global Economy

Air transportation also allows business and industry to respond faster and more effectively to market demand, to reach new markets around the globe, obtain the best prices, and participate in just-in-time delivery to reduce manufacturer and business inventory costs. The U.S. Postal Service and others can deliver goods and mail faster and more efficiently with air transportation than with any other mode of transportation, thus enabling ecommerce. Because of the U.S. air transportation system and aviation-enabled precision agriculture techniques, farmers can cut costs, save time, and ensure that the entire agricultural operation is more efficient. Farmers can also ship agricultural

[19] National Science and Technology Council, National Research and Development Plan for Aviation Safety, Security, Efficiency and Environmental Compatibility. November 1999.

products and other perishables while still fresh, and the nation can access a greater variety of fresh produce from U.S. and international markets year around. And aviation manufacturing is a consistent net exporter, adding tens of billions of dollars annually to the nation's balance of trade.[20]

- The air transportation industry contributes $80-to-$90 billion per year to the national economy—approximately 1% of GDP.
- The air transportation industry employs 800,000 Americans in high quality jobs, second only to trucking in the transportation sector. [21]
- International growth in the air transportation industry exceeds growth in the GDP—between 5%-6% annually. [22]
- Air freight accounts for 27% of the value of U.S. exports and imports and is growing at more than 10% annually. [23]
- The air transportation industry produces and uses a broad base of technologies—from computing and simulation to advanced materials supporting a high technology industrial base. [24]

Maintaining National Security

Because of the U.S. air transportation system, the nation can defend its people and project power when and wherever necessary. The nation relies on the U.S. air transportation system and other aerospace capabilities to patrol the skies and transport government troops and officials during periods of heightened security and actual threat. Defense aviation drives the research, development and implementation of the most advanced technology to provide unparalleled protection for the U.S. and other nations in times of need. [25]

Enhancing Public Health and Safety

Because of the U.S. air transportation system, firefighters and other first responders can react faster and more effectively to wildfires, earthquakes, and other disasters. Firefighters can map hundreds of miles and communicate location data to the field in near-real time using aviation-based wildfire mapping. Paramedics, physicians, and critical care nurses can transport donor organs and critically ill and injured patients via air ambulances and mobile intensive care units to hospitals, cutting critical minutes off transport time. Local, state, and federal law enforcement can monitor drug traffic and other illegal activity in border regions more effectively, covering thousands of miles with fewer workers.

- The Bureau of Land Management relies on the nation's air transportation system to monitor and manage 261 million acres of public land primarily in 12 western states.

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[20] ibid

[21] Aeronautics Vision for the 21st Century, NASA White Paper, March 5, 2001, www.ewh.ieee.org/soc/aes/Blueprint.doc

[22] ibid

[23] ibid

[24] ibid

[25] ibid

- The National Interagency Fire Center and its member agencies—Bureau of Land Management, Bureau of Indian Affairs, U.S. Fish and Wildlife Service, National Park Service, National Weather Service, and U.S. Forest Service—all rely on the U.S. air transportation system to map wildfires on public lands across the United States. Using remotely piloted aircraft, remote sensors, and information technology, agencies can send over-the-horizon pictures and data to firefighters in near-real time.

Protecting the Environment

Because of the U.S. air transportation system, state and federal departments of fish and game and other environmental organizations can monitor, manage, and protect natural resources and public lands more effectively. Using aircraft to cover millions of square miles annually, environmental organizations can balance the needs of local communities with the ability of ecosystems to support soil, water, forests, wildlife, fish, and recreational resources.

Traveling to and from the U.S.

Because of the U.S. air transportation system, travelers can traverse thousands of miles in hours instead of days to attend business, social, educational, and family functions.

- Air carriers enplane more than 500 million passengers and fly more than 500 billion passenger miles annually, accounting for 25% of all individual trips over 500 miles, 50% over 1000 miles, and 75% over 2000 miles. [26]

- Air travel accounts for 24% of tourism-related sales ($170 billion out of $700 billion in 2002), second only to hotels and lodging, which accounts for 28%, followed by restaurants, which accounts for 18%.[27]

ENABLING AIR TRANSPORTATION TOMORROW: SAFETY, SECURITY, AND ENVIRONMENTAL COMPATIBILITY

The U.S. economy depends on a robust air transportation system and stands to lose billions annually if future capacity fails to keep pace with anticipated demand. A national program to transform the system is therefore essential to preserve the nation's economic prosperity.

However, such a transformation depends on keeping safety, security, and environmental concerns essential first priorities. A public that lacks confidence in any aspect of air transportation will either stay home or seek an alternative mode of travel and in any case will avoid flying.

Long-term, high-payoff aerospace technologies must, therefore, not only aim to preserve U.S. global aerospace leadership in the 21st century and safeguard America's economic prosperity; they must also seek to improve quality of life by improving and protecting the environment, increasing mobility and safety, and ensuring the continued security of the nation and its people.

Increasing Safety

Commercial air transportation is one of the safest modes of transportation. According to a recent estimate by the National Safety Council, the fatality rate for airline passengers per mile traveled is

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[26] Aeronautics Vision for the 21st Century, NASA White Paper, March 5, 2001, www.ewh.ieee.org/soc/aes/Blueprint.doc

only about 5% of the rate for motor vehicle passengers, and even slightly better than for rail or transit bus riders (Figure 2-1).[28]

Figure 2-1. Fatality Rates by Mode of Travel: 1997-1999 Average Deaths per 100 Million Passenger Miles	
Type of Vehicle	**Death Rate**
Automobiles	0.87
Intercity and commuter railroads	0.06
Transit buses	0.05
Intercity buses	0.04
Airlines	0.04
Heavy, light, and other rail vehicles	Not reported

Source: Injury Facts, National Safety Council, 2001.

Unfortunately, GA is not as safe as commercial air transportation. In 2000, almost seven times more GA and air taxi passengers died (664) than commercial airline passengers (92), even though commercial airlines flew many more passenger miles. The spike in commercial fatalities in 2001 was due to the tragedy of September 11. It is encouraging to note, however, that there were no reported commercial air transportation fatalities in 2002. In addition, the overall trend in GA fatalities consistently dropped since 1970 and now is less than one-half of the total for that year.

Continued increases in future aircraft operations will also increase the possibility of accidents. More aircraft will be using a fixed amount of airspace. Aircraft will be operating in closer proximity to each other both in the air and on the ground, increasing the burden on airport traffic managers and air traffic controllers. There may also be a wider variety of aircraft types with different operating characteristics all simultaneously using the same airports.

NASA and DOT Response

Both NASA and the FAA support research and development projects to enhance air transportation system safety. NASA's Aviation Safety Program seeks "to 1) develop and demonstrate technologies that reduce aircraft accident rates; and 2) develop technologies that reduce air transportation injuries and fatalities when accidents do occur."[29] In pursuit of that goal, the program develops systems safety, vehicle safety, and weather safety technologies. Specific applications include air transportation system monitoring and modeling, accident prevention, and search and rescue (system safety); accident mitigation and synthetic vision (vehicle safety); and weather accident prevention and icing research (weather safety).[30] Once developed and validated, NASA transfers the technologies to the FAA and the aeronautics industry for production and deployment.

The DOT's safety goals seek to reduce commercial air transportation fatal accidents to 0.01 per 100 thousand departures and GA fatal accidents to 325 by 2008. The agency uses hard data to detect problems and disturbing trends, takes action to prevent accidents, and uses technology where it brings the greatest safety benefits. [31] The FAA's safety goal seeks to reduce U.S. air transportation fatal accident rates by 80 % from 1996 levels by 2007. [32] Specific FAA safety-related research areas include: aircraft surface collisions and airport safety; the reliability of new software and cyber security; aging aircraft, structures and components; human factors and aerospace medicine; minimizing weather-related accidents and the unintended adverse consequences of new security systems; and commercial space transportation safety. [33]

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[28] There are other measures of comparison for transportation safety, such as fatalities per trip instead of miles traveled. Regardless of the measure chosen, however, commercial aviation remains one of the safest modes of travel.

[29] NASA Aviation Safety Program Office at http://avsp.larc.nasa.gov/about.html

[30] NASA Aviation Safety Program Office at http://avsp.larc.nasa.gov/program.html

[31] U.S. DOT, Strategic Plan 2003-2008: Safer, Simpler, Smarter Transportation Solutions, September 2003, p. 21.

[32] 2003 National Aviation Research Plan, p. 1-3

[33] Ibid, pp. 1-2, 1-3.

Many FAA's non-safety research activities also enhance air transportation safety or do not diminish it. For example, reducing aircraft in-flight separation standards without compromising safety will enhance both NAS capacity and efficiency. The Safe Flight 21 program validates the potential of advanced technologies in such areas as communications, navigation, surveillance, and air traffic procedures to improve NAS efficiency, capacity, and safety.[34] In undertaking these important efforts, the FAA maintains a variety of cooperative agreements and formal partnerships with dozens of other federal agencies (NASA, DOD, National Oceanic and Atmospheric Administration, etc.); international organizations (ICAO, Eurocontrol, Transport Canada, etc.); universities and non-profit research institutes (Embry-Riddle Aeronautical University, Massachusetts Institute of Technology, University of Illinois, Southwest Research Institute, etc.); and hundreds of private air transportation and aerospace companies, both in the United States and overseas.

Ensuring Continued National Security

Terrorists have targeted international air transportation for decades, and the tragic events of September 11, 2001 dramatically increased the severity of the threat when terrorists for the first time turned commercial aircraft into deadly missiles to be used against buildings and civilians in New York and Washington. Transportation Security Administration (TSA) officials say they believe that terrorists will continue to consider attacks against commercial airplanes in the United States and abroad and seek new ways to circumvent enhanced security measures.[35]

Obstacles. Several technologies hold promise for applications in aviation, but quality of life concerns could impede their development and implementation—e.g., concern over the accuracy and speed of new security equipment; passenger privacy and intrusiveness; personal safety associated with the use of chemicals and energy sources employed by security systems; additional delays at airport terminals caused by new screening processes; and the cost of installing and operating additional security systems. Additional research could help resolve these issues and accelerate the technology development process. Above all, a coordinated and integrated approach to combining these various technologies and systems into an effective, seamless airport security environment is essential. [36]

FAA, DHS/TSA and Other Government Response

The federal government continues to respond with force at home and abroad, pursuing a global war on terrorism, creating a new federal agency to protect the nation against further terrorist attacks, and passing new legislation that increases federal responsibility and resources.

- DHS analyzes threats and intelligence, guards the nation's borders and airports, protects critical infrastructure, and coordinates national responses to attacks and emergencies. Component agencies have already implemented new security measures and plan more.
- DHS/TSA federalized security screening personnel at U.S. airports, strengthened procedures for screening passengers and carry-on bags, and mandated the use of sophisticated and expensive luggage inspection equipment at airports. Pending legislation could require TSA to develop a strategic plan for screening air cargo and inspecting both cargo itself and cargo shipping facilities. Cargo in airline holds and air cargo planes is not covered by the air transportation security bill passed by Congress in 2001 following the terrorist attacks in New York and Washington. TSA is exploring systems to improve and streamline screening of air passengers, including a computer-assisted passenger prescreening system known as CAPPS II, to develop more effective explosive-detection technologies and to create uniform credentials for transportation workers.
- The Homeland Security Advanced Research Projects Agency, created in 2003, identifies and develops revolutionary new technologies that can improve detection capabilities

[34] Ibid, pp. 2.2-5, 2.2-16.

[35] Washington File, Nov 6, 2003. http://www.iwar.org.uk/news-archive/2003/11-05-5.htm

[36] *Assessment of Technologies Deployed to Improve Aviation Security: First Report,* p. 62.

against biological, chemical, nuclear, and other categories of weapons of mass destruction. The agency will also accelerate research into computer security, cyber terrorism, enhanced passenger screening, and weapons detection capabilities.

- U.S. Customs and Border Protection will collect cargo information necessary to identify high-risk shipments that could threaten the safety and security of the United States.
- The FAA's Aviation Security functions, including research into detection systems and equipment are now part of DHS. Such increased attention to developing and introducing new security technologies and practices should be continued.
- TSA will establish a common identification card for up to 15 million workers who access secure areas of the air transportation system or who handle hazardous materials in their work. The Transportation Worker Identification Credential (TWIC) will contain an embedded computer chip, bar codes, and a magnetic stripe with biometric and personal information.
- A new legislatively mandated "smart border" initiative known as the U.S. Visitor and Immigrant Status Indication Technology (VISIT) Program requires foreign visitors to the U.S. after January 2004 to carry visas embedded with biometric identifiers (photographs and fingerprints).[37]

Advanced Technologies

Advances in biometric technologies could improve the effectiveness of passenger screening. Biometric systems measure an individual's unique physical or behavioral characteristics to verify identity. Common biometric systems used in security today include fingerprints, hand and finger geometry, facial recognition, and iris or retinal scanning.

- Several U.S. and foreign airports currently use or have tested biometric systems to identify passengers and airport workers, as shown in Figure 2-2.
- The International Civil Aviation Organization (ICAO) also agreed on biometric standards for immigration and border control. ICAO chose facial recognition as the globally interoperable biometric, along with contact less integrated circuit (IC) chips to store information in machine readable travel documents."[38]

Advanced sensors and related new technologies in development could enable the detection of weapons, explosives, and chemicals with greater accuracy. Technologies include:

- Active and passive millimeter-wave and active x-ray imaging; back-scatter x-rays; x-ray diffraction; microwave screening; trace detection using ion mobility spectrometry and gas chromatography; chemiluminescence; computerized tomography; nuclear quadrupole resonance; and pulsed fast neutron analysis .[39]

NASA also increased security research following the events of September 11. The Aviation Safety Program became the Aviation Safety and Security Program and will focus on areas where NASA expertise could make a significant contribution to security, including:

- Hardening of aircraft and their systems

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[37] Section 303(b) of PL 107-173 at http://thomas.loc.gov/cgi-bin/bdquery/z?d107:h.r.03525, and "U.S. VISIT details discussed," FCW.COM, May 19, 2003. This deadline may be delayed for one or more years, depending on other nations' ability to manufacture new passports that meet these requirements.

[38] *Biometric Identification to Provide Enhanced Security and Speedier Border Clearance for Traveling Public,* available at http://www.icao.int/cgi/goto.pl?icao/en/nr/pio200309.htm.

[39] Two NMAB summaries of detection technologies are available from the National Academy Press in Washington DC. : A*irline Passenger Security Screening,* 1996, and *Assessment of Technologies Deployed to Improve Aviation Security: First Report,* 1999.

- Secure airspace operation technology
- Improved systems to screen passengers and cargo information
- Sensors designed to better detect threats

Other advanced technologies on the horizon could allow pilots to monitor the location of any aircraft at any time and to monitor unexpected deviations from the flight path. Surreptitious emergency transmissions from such aircraft, or the ability to deny flight control to unauthorized passengers, could mitigate security incidents. Such capabilities could help ensure that the safety and security of the air transportation system continues to improve along with increases in demand.

Solutions

The air traffic management system of the future must operate at even higher levels of safety and reliability than today to accommodate future increases in usage. Pilots, controllers, dispatchers, and service technicians must enhance public health and safety by working to eliminate aviation-related deaths and injuries, while government, industry, and academia must provide necessary tools. Future research in enhanced vehicle system technologies could reduce the wake created by large aircraft, solving a safety problem that has plagued the industry. Such changes could lead to new designs with shorter take-off and landings, which, in some cases, could enable a complementary benefit of greater access at more locations and airports.

Figure 2-2. Biometrics Use at Airports (Tested or Deployed)

Fingerprint	Hand Geometry	Facial Recognition	Iris Scan
Albany	Boise	Boston	Amsterdam (Netherlands)
Boson	San Francisco	Ft. Lauderdale	Charlotte
Charlotte	San Jose	Manchester, NH	London (Heathrow)
Corpus Christi	Salt Lake City	Keflavik (Iceland)	
Kansas City	Manchester (UK)	St. Petersburg	
Long Beach	Portland, Maine	Yosemite	
Orange County	23 U.S. and Canadian INPASS airports		
Orlando			
Palm Springs			
Philadelphia			
Reno/Tahoe			
Richmond			
St. Louis			
Tucson			
Tulsa			

Enhancing Environmental Compatibility

Technological advances over the past 40 years enabled a ten-fold improvement in aviation safety, doubled fuel efficiency while reducing missions, cut costs in half, and reduced noise by an order of magnitude. [42] However, environmental issues will likely impose the fundamental limitation on air transportation growth in the 21st century. [43] Therefore, any national initiative to transform the air transportation system must seek to ensure the long-term environmental compatibility of the air transportation system with demand-based growth. Such an achievement will require research and

[42] ibid

[43] National Science and Technology Council, *National Research and Development Plan for Safety, Security, Efficiency and Environmental Compatibility,* November 1999. page 51.

technology development to minimize environmental impact, particularly with respect to aircraft noise and emissions.

Noise. Opposition to noise from aircraft operations and ground-based activities in the U.S. and other nations continues to limit U.S. airport and runway expansion. Key concerns focus on the impact of high noise levels on daily activities and the evidence that exposure to airport noise could lead to serious health problems.

Emissions and global warming. Transportation systems in general contribute to poor air quality and carbon emissions due to dependence on fossil fuels and the scarcity of low- or non-emitting alternatives.[46] As transportation activities increase, these impacts will also rise.

Aircraft, ground vehicle, and other air transportation activities at airports contribute only about 0.5% of total U.S. air pollution.[47] Subsonic aircraft NO_x emissions in the upper troposphere and lower stratosphere (about 25,000 to 40,000 feet) tend to increase ozone levels, while supersonic aircraft emissions in the stratosphere (about 50,000 to 60,000 feet) tend to decrease ozone levels.[48]

Air transportation has a limited range of alternative fuels and propulsion systems compared to other modes of transport, and research into the potential for hydrogen propulsion for aircraft is several decades away from providing a solution. [49] Thus, air transportation emissions could be among the last to be reduced as other transportation modes switch to cleaner fuels and technologies. This will increase the visibility of air transportation as a major continuing contributor to emissions and global warming, which could spark considerable opposition to increasing air transportation activities without corresponding emission reductions.

It is estimated that global aircraft emissions are currently responsible for about 3.5% of all human-generated global warming; however, this amount may reach 5% of the total by 2050.[50]

Over the past thirty years, the average fuel consumption of the U.S. commercial air transportation fleet has decreased by more than 60%, partly because of the increase in average load factors but also due to technological improvements.[53] However, this trend itself will not be sufficient to reduce total aircraft emissions. Recent studies suggest that overall aircraft efficiency can be expected to improve by about 1.7% annually, while air transportation demand will be increasing at a 4% to 6% annual

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[46] Transportation is the source of 30 % of total U.S. volatile organic compound (VOC), 40 % of oxides of nitrogen (NOx), 43 % of particulate matter (PM-10 or less than 10 microns), and 60% of carbon monoxide (CO) emissions. *Ibid,* pp. 295-299

[47] *U.S. General Accounting Office, Aviation and the Environment: Strategic Framework Needed to Address Challenges Posed by Aircraft Emissions,* February 2003, GAO-03-252, p. 1.

[48] Intergovernmental Panel on Climate Change (IPCC), *Aviation and the Global Atmosphere,* Geneva, Switzerland, 1999; cited in Joosung Joseph Lee, *Historical and Future Trends in Aircraft Performance, Cost and Emissions,* Master of Science Thesis, Massachusetts Institute of Technology, September 2000, p. 29.

[49] An *Aviation Week and Space Technology* article of September 9, 2002 (p. 26) discussed a $315,000, three-to-six month contract that Boeing received from the U.S. Defense Advanced Research Projects Agency to design a fuel-cell-based aviation propulsion system for small and extremely long-endurance unmanned surveillance or communications relay aircraft. NASA and the European Community are also committing government funds to explore hydrogen propulsion for aircraft.

[50] When measured in terms of *radioactive forcing*, or changes in the energy balance in the atmosphere. *Historical and Future Trends in Aircraft Performance, Cost and Emissions*, p. 9.

[53] Efficiency is measured in terms of gallons of fuel per revenue passenger mile. Historical and Future Trends in Aircraft Performance, Cost and Emissions, p. 42.

rate.[54] This means that total fuel consumption and related CO2 emissions could double between 1995 and 2025, even though fuel efficiency may increase by one half (See Figure 2-3).

Figure 2-3. Total Aviation Fuel Consumption, CO2 Emissions and Economic Characteristics, 2025/2050				
	Metric	1995	2025	2050
Total RPMs	Miles (billion)	1576	4681	8658
Load factor		0.673	0.758	0.800
Fleet fuel efficiency	ASM/gal	53.6	71.7	101
Fuel consumption	RMP/gal	0.0277	0.0184	0.0124
Total fuel consumption	Gallons (billion)	43.7	86.1	107
Co2 emissions	Kg (billion)	419	827	1031
DOC/RPM	Cents	4.41	2.98	2.04
Price per seat	$ (thousands)	247	306	376

Source: Historical and Future Trends in Aircraft Performance, Cost and Emissions, p. 121.

Given the current state of air transportation and propulsion technologies, there is also a similar unfortunate tradeoff between lowering aircraft noise levels and increasing fuel usage and emissions. Another study reported that long-range aircraft cruising at 32,000 feet instead of 40,000 feet can reduce greenhouse effects by about 25% but at a cost of using 11% more fuel. Thus, environmental goals can sometimes conflict.[55] As the U.S. Government Accounting Office, (GAO) summarized, "While NASA and engine manufacturers have made continuous improvements for decades in technologies that have improved fuel efficiency, decreased noise, and decreased all emissions including nitrogen oxides, the design of the newest generation of engines has resulted in trade-offs that favor fuel efficiency and increased nitrogen oxides."[56]

Trade Offs With Advanced Technology

Although they may be quieter, more fuel efficient, and partially cleaner, many advanced engines generate higher levels of certain pollutants than earlier models. The GAO estimates that engines in the newer Boeing 737 models generate 40% more nitrogen oxides during takeoffs and landings than the older-model 737s they replace, even though they generate fewer carbon-based emissions. (See Figure 2-4). This same pattern occurs when replacing older Boeing 747-400 models with newer Boeing 777-200ERS.

Figure 2-4: Takeoff/Landing Emissions (in pounds) for Older and Newer Boeing 737s			
Emission	Older 737	Newer 737	Difference
Nitrogen oxides	12.1	17.8	47% increase
Carbon monoxide	16.8	10.7	37% decrease
Hydrocarbons	1.2	1.1	10% decrease

Source: GAO-03-252, February 2003, p. 23.

NASA and the FAA continue to fund research programs to reduce the amount of noise generated by air transportation activities. NASA's Quiet Aircraft Technology program aims to "reduce the perceived noise levels by half in ten years, and by three-quarters in twenty-five years, effectively containing the noise within the airport boundary."[57]

NASA and industry response. NASA is working with aircraft engine manufacturers to develop newer, quieter, and more efficient aircraft engines. NASA's Ultra Efficient Engine Technology Program focuses on reducing NO_x emissions by using lean-burning jet engine combustors.

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[54] Ibid, pp. 3, 19-20, 108-110, 121. See also Airport Operators Association, British Air Transport Association, Royal Aeronautics Society, and Society of British Aerospace Companies, *Air Travel – Greener by Design: The Technology Challenge.* Report of the Technology Sub-Group, no date (2002 or 2003). Available at www.raes.org.uk/gbd/

[55] *Air Travel – Greener by Design: The Technology Challenge,* pp. 3, 6, 8.

[56] *Aviation and the Environment* , p. 27.

[57] http://avst.larc.nasa.gov/qat.html.

Researchers have been able to reduce the noise generated by jet engines by increasing the size of bypass fans used to increase fuel efficiency and by redesigning the fan blades. NASA and industry partners are also investigating other advanced technologies to reduce engine noise and emissions, such as active noise control via electronics and computerized control of engine functions.[58] Improved aerodynamic efficiency, reductions in aircraft weight through advanced lightweight alloys and composite materials, and increasing aircraft load factors will further reduce fuel consumption and emissions.[59]

FAA response. The FAA developed the Emissions and Dispersion Modeling System to estimate the level and types of emissions from airports and their dispersal into the atmosphere under varying weather conditions. [60] In addition, the FAA and Eurocontrol are collaborating to develop a global air traffic emission database, including such inputs as flight movements and schedules, aircraft performance data, and aircraft inventories. The System for Assessing Aviation's Global Emissions (SAGE) in the U.S. and AERO2K in Europe[61] could provide useful tools to help determine the location and sources of aviation-related pollution.

FAA computer models analyze airport noise, and the agency recently established the Center of Excellence for Aircraft Noise Mitigation to coordinate the efforts of government, industry, and academia. It also joined with other government agencies to create the Federal Interagency Committee on Aviation Noise to encourage research and conduct public forums on the topic.[62]

Airports and government response. State air quality agencies in California, Texas, and Massachusetts have negotiated with area airports to implement strategies to reduce emissions. The EPA will begin implementing even stricter ambient air quality standards in late 2003, especially for ozone, thus increasing the number of major commercial airports in ozone non-attainment areas from 26 to 38. The EPA reviews major airport construction project proposals in certain areas to determine whether project-related emissions will adversely influence state goals to reduce emissions and can compel airports to reduce equivalent emissions from other sources. Although limited federal and state financial assistance is available from the FAA's Inherently Low-Emission Airport Vehicle Pilot Program and other sources, funding is insufficient to assure major progress in reducing emissions.

In response to environmental concerns, many U.S. airports have proactively undertaken action to reduce emissions. Since ground support vehicles are a significant source of airport-related emissions, one common action is to convert these vehicles and shuttle buses to cleaner burning conventional (gasoline or diesel) fuels or alternative fuels such as compressed natural gas or electricity.[63] Other measures include decreasing aircraft taxiing time, limiting engine thrust during takeoff, providing electricity and air-conditioning to parked aircraft (allowing them to shut off their onboard auxiliary power units), and establishing employee ridesharing programs and shuttle bus service.

Many airports have also installed monitoring systems to measure noise levels, prohibited aircraft that do not meet certain noise limits, paid costs to soundproof nearby dwellings, schools and businesses, and agreed to restrict operating hours and takeoff/landing routes. New aircraft also come equipped with increasingly quiet aircraft engines and many aircraft operators use recently developed "hush kits" to retrofit older planes with new technology that can reduce noise.

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[58] Aviation and the Environment, pp. 59-63.

[59] *Historical and Future Trends in Aircraft Performance, Cost, and Emissions,* p. 138.

[60] *Aviation and the Environment*, p. 45, 47-48.

[61] Sophie Michot and Ted Elliff (Eurocontrol), Gregg Fleming and Brian Kim (DOT/Volpe Center), Curtis Holsclaw, Maryalice Locke and Angel Morales (FAA), Flight Movement Inventory: SAGE-AERO2K, 2003.

[62] Federal Aviation Administration, *2003 National Aviation Research Plan: Charting the Next Century of Flight,* Washington DC, February 2003, pp. 2.3-4 and 2.3-5.

[63] *Ibid*, p. 41.

Revolutionary Technologies [64]

Advances derived from the fusion of biotechnology, nanotechnology, and information technology could enable revolutionary changes in aircraft, providing orders of magnitude increases in safety and reliability while vastly lowering operating costs. On board intelligence will be able to monitor aircraft health and predict the need for maintenance before problems occur, and in time, aircraft could even have the ability to self-repair. Revolutionary new nanotechnology composites could enable the construction of aircraft that are 100 times stronger than steel but weigh half as much as conventional aircraft, which could result in fuel savings of 25% and dramatically increase safety. New computational tools will allow fully integrated vehicle engine design, integrated health management, and management of the total vehicle air flow inside the engine and outside the aircraft. New integrated propulsion and vehicle technology advancements could optimize subsonic flight regimes, with twice the thrust to weight ratios, and enable sustained supersonic flight with minimal impact due to sonic booms or other environmental concerns for both civilian and military applications.

"Smart" systems. Future manufacturers will no longer build aircraft from multiple, mechanically connected parts but will instead use "smart" materials with embedded sensors and actuators. Sensors will measure pressure over an entire surface of a wing and direct actuator response. Actuators will change the shape of the wing for optimal flying conditions. The control surface will be integrated with the wing instead of functioning as an appendage. Intelligent systems made of these smart sensors, microprocessors, and adaptive control systems will enable vehicles to monitor performance, environment, and human operators in order to avoid crashes, mishaps, and incidents. Distributed as a network throughout the structure they will provide the means for imbedding a virtual "nervous system" in the structure, stimulating it to create physical response. Wing shape may even be changed during flight to control the vehicle, eliminating the need for the weight and complexity of flaps and conventional control surfaces. Intelligent systems will also sense any damage or impending failure long before it becomes a problem.

Nanotechnology and vehicle design. Aircraft made from revolutionary nanotechnology composites could weigh half as much as conventional aircraft and be extremely flexible. Wings could re-form in flight to optimal shapes, remain extremely resistant to damage, and potentially "self heal." The high strength-to-weight ratio of nano materials could also enable new vehicle designs capable of withstanding crashes and protecting passengers against injury.

Nanotechnology and aircraft engines. Application of advanced lightweight materials with intelligent flow control and active cooling could enable thrust-to-weight ratio increases up to 50% and fuel savings of 25%. Further advances in integrating these technologies could lead to novel engine concepts that simplify the highly, complex rotating turbomachinery. Other future concepts include alternative combustion approaches and the potential to move toward hybrid engines that employ innovations such as pulse detonation engine core. Combined with intelligent engine control capability, such an approach could able integrated internal flow management and combustion control. It also has the potential to integrate both the airframe and engine systems for unprecedented efficiency and directional control capability.

Information technology and increasingly complex future systems. Future aircraft and air traffic management systems will require new computational tools and advanced information technology capable of dealing with the increased complexity and revolutionary performance. High speed computing will enable development of large scale models and simulations of advanced operational concepts, next generation vehicles, and will enable fully integrated vehicle engine design, integrated health management, and management of the total vehicle air flow both inside the engine and outside the aircraft.

Advanced propulsion. In the very long term, comparable advances in electrical energy storage and generation technology, such as fuel cells, could completely change aircraft propulsion. New fuel cell

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[64] Aeronautics Vision for the 21st Century, NASA White Paper, March 5, 2001, www.ewh.ieee.org/soc/aes/Blueprint.doc

power systems could enable zero emissions, and the only noise would come from the air flowing over the vehicle. Future aircraft might be powered entirely electrically. Thrust may be produced by a fan driven by highly efficient, compact electric motors powered by advanced hydrogen oxygen fuel cells. Success in this effort could end the nation's dependence on foreign sources of energy for transportation.

These and other revolutionary materials, technologies, and intelligent systems could enable the design and manufacture of aircraft capable of meeting a range of 21st century performance requirements—e.g., greater range, maneuverability, and fuel efficiency with minimal emissions, noise, and maintenance requirements. Such aircraft could be flown in an air transportation system that allows trouble free, on-demand travel to any location.

The potential benefits of these materials and technologies could address many of the quality of life concerns associated with air transportation growth in the 21st century. These and other capabilities in the future will help ensure that the safety and security of the air transportation system continues to improve along with increases in demand.

Solutions

Aircraft and airports must make significant reductions in the emissions associated with their activities or risk possible new air transportation taxes, landing fees, or legislative action to limit operations. Depending on public concern over air pollution and greenhouse gases, these limitations could be either voluntary or mandatory, and could be imposed by local, state, and national agencies or even by international organizations or treaties. Options to encourage reduction in overall air transportation emissions include:

- Increase research and development for quieter, cleaner and more efficient aircraft engines and structures and ground-based airport equipment and vehicles, as well as for enhancing understanding of aviation-related emissions and their impacts
- Implement stricter national and/or international emissions standards
- Impose air transportation taxes and landing fees based on emissions levels
- Adopt emissions trading schemes
- Provide government incentives to encourage voluntary agreements

PART 2. ECONOMIC VALUE OF AIR TRANSPORTATION

This section quantifies the role that air transportation and related industries play in the U.S. economy relative to domestic and international passenger travel, transportation of goods, aircraft manufacturing, and other aviation-related activities that are related to GDP, national output, and employment. This section also presents a methodology for assessing the economic cost of a projected NAS capacity shortfall in 2015 and 2025.

ASSESSING THE ECONOMIC SIGNIFICANCE OF THE AVIATION AND AIR TRANSPORTATION SECTORS

The potential value of transforming the air transportation system to meet future needs has little to do with the economic impact of the air transportation industry on the nation today. Economic impact studies provide a static measure of an industry's share of the economy at a given point in time and are not useful tools to measure social benefits that would derive from government programs or investments. The SEDF study team developed economic data and analytic tools to express the national value of transformation in terms more relevant to government planners and decision-makers. They include:

- Increases in average airfares if system capacity and infrastructure cannot grow to meet demand
- Fewer passenger trips by commercial air transportation and general aviation
- Reduced ability to use travel time productively, without delay or disruption
- Increased costs and reduced reliability for the transport of goods by air

A benefit-cost analysis generally offers the best way of assessing such measures because it focuses on 1) the potential costs to the economy if NAS capacity is not increased to meet future demand and 2) the research, development, and implementation costs of increasing capacity to meet future needs. Such a benefit-cost analysis would consider:

- Increases in costs faced by airlines, airports and air traffic service providers due to growing congestion and system delay, making it more difficult to take advantage of economies of scale or scope, more efficient production processes, and new technology
- Increased delays affecting passengers due to increasing demand being placed on static and increasingly inadequate system capacity
- Average fare levels for travelers with and without increases in system capacity
- Economic losses due to foregone travel or shifting of travel to other modes or activities if NAS capacity fails to keep pace with future demand
- Any induced demand effects that will be foregone in the absence of a more capacious air transportation system

LITERATURE REVIEW

The SEDF study team reviewed several studies that measured the economic value of air transportation within the national economy. [65] The scope of these studies extended across civil air transportation, aerospace manufacturing, military, and other aerospace activities. The team also reviewed Office of Management and Budget (OMB) and other requirements for analyzing federal investment in such areas as increasing NAS capacity. The purpose of the literature review was to identify the link between the economic activity of a region or a country and the availability of air transportation. More specifically, the available literature was reviewed in order to determine what information was obtainable on the following topics:

- Economic impacts of aviation
  - Present economic impacts
  - Future economic impacts
- What do studies say about current impact on U.S. economy?
  - Magnitude?
  - What is included?
- International trade impacts of aviation
- Measuring benefits of investment in air transportation infrastructure
- What does OMB say about using economic impact measures?

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[65] The review of the literature is contained in Appendix F.

- What do studies say about benefits of future investment?
  - How are they measured?
  - What is their magnitude?
- What are key assumptions?

Economic Impact Studies

Economic impact studies measure the "value" of the industry in terms of current economic output, contributions to GDP, earnings, jobs, or similar measures. Regional economic impact studies have been used effectively to promote airport improvements. The results of such studies depend on the definition of the industry sectors to be included, whether and how related industries such as tourism are included, and the way various economic multipliers (which measure the effects of the turnover of dollars spent by direct participants in the air transportation industry as they flow through the larger economy) are used in the study. Such studies generally represent a static measure of the value of the industry at a point in time.

However, relying on such studies to estimate the value of a national research and technology development program focused on transforming the U.S. air transportation system to meet 21st century needs can be problematic. One reason is that the use of different sectors to define the aerospace or air transportation industry makes it difficult to compare findings. In addition, a static measure of the industry's share of the economy at a given point in time may have little relevance to estimating future benefits. Even more importantly, the studies rely, in part, on economic multipliers to estimate economic impacts, although OMB guidelines explicitly advise against their use to measure the social benefits that may derive from government programs or investments.

> "Employment or output multipliers that purport to measure the secondary effects of government expenditures on employment and output should not be included in measured social benefits and costs."[66]

The exclusion of economic impacts derived from multipliers is based on the OMB-mandated assumption that resources in an economy are likely to be fully employed. FAA's benefit-cost guidance for capacity-related airport projects also cautions against using multiplier-based estimates because they implicitly assume the availability of unemployed labor and surplus productive capacity in the economy.[67] Thus, economic impact studies do not meet the requirements for investment analysis of federal programs.[68]

Finally, economic impact studies consider only short-term economic effects. Thus, $1 billion spent on the air transportation system would have roughly the same effects on income and employment as a $1 billion spent elsewhere in the economy.[69]

Prior Studies

There have been a number of economic impact studies estimating the value of air transportation on the U.S. economy. Recent studies reviewed by the SEDF study team include:

- *The Economic Impact of Civil Aviation on the U.S. Economy* – Update 2002," by Wilbur Smith Associates, for the FAA [70]

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[66] OMB Circular A-94, p. 6. This review also examines recent exercises in aviation demand forecasts.

[67] *FAA Airport Benefit-Cost Analysis Guidance*, Office of Aviation Policy and Plans, Federal Aviation Administration, December 15, 1999, pp. 60-61.

[68] OMB Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.

[69] Saurav Dev Bhatta and Matthew P. Drennan, "The Economic Benefits of Public Investments in Transportation: A Review of the Recent Literature," J*ournal of Planning Education and Research*, p. 289.

[70] *The Economic Impact of Civil Aviation on the U.S. Economy – Update 2002*, Wilbur Smith Associates, Prepared for FAA ASD-300 NAS Programming and Financial Management, April 2003.

- *The National Economic Impact of Civil Aviation*, DRI-WEFA, Inc., for an industry group [71]

- *Final Report of the Commission on the Future of the United States Aerospace Industry*, for the President and Congress

The Economic Impact of Civil Aviation on the U.S. Economy. Completed for the FAA, this study considered commercial air transportation including airlines, airports, travel agents, aircraft manufacturing, and air passenger spending. It also considered the economic impact of general aviation, including fixed base operators, flight schools, aircraft manufacturing, and GA passenger spending. The study found the following annual impacts for the year 2000:

- $172 billion in direct impacts

- $514 billion in total impacts on GDP which represents 5% of total U.S. GDP

- 11.6 million jobs were dependent on air transportation

About two-thirds of the GDP contribution derives from direct and indirect impacts and one-third from induced impacts. The SEDF team believes that the direct and indirect GDP contribution of an industry is the best measure of its economic importance.

The National Economic Impact of Civil Aviation. Completed for a group of air transportation industry associations and the Boeing Company, the study considered similar sectors as the FAA study but concluded that the economic impact of air transportation was approximately 9% of GDP. Its estimate of aviation-related jobs was close to that of the FAA study, at 11 million civil aviation dependent jobs. [72]

Final Report of the Commission on the Future of the United States Aerospace Industry. Completed for Congress, the report concluded that the aerospace industry accounts for more than 15% of GDP and supports more than 15 million high quality jobs. [73] This number and the Global Insights estimate differ in that the Commission's impact estimate includes military and space sectors of the economy.

While the magnitude of the numbers reported in the studies depends on assumptions about current resource utilization, the breadth with which the industry is defined, and the availability of substitutes, all of the economic impact literature reviewed pointed to the large role that air transportation plays in the U.S. economy. The important and unique role of the U.S. air transportation industry will continue to grow as world markets continue to become global in scope.

ECONOMIC LINKAGES: AIR TRANSPORTATION AND OTHER INDUSTRIES AND SECTORS

The value to the nation of an air transportation system able to provide services demanded by diverse users can be illustrated by the system's many linkages to other sectors of the economy. The demand for transportation services is often described as a "derived" demand, because individuals and firms rarely value transportation for its own sake. Instead, transportation is valued as an intermediate input for some separate production or consumption process. For civil aviation, examples include the transport of high value or perishable goods, such as fresh flowers, fish, or computer components, to distribution centers or assembly facilities.

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[71] *The National Economic Impact of Civil Aviation*, prepared by DRI-WEFA, Inc., a Global Insight company in collaboration with the Campbell-Hill Aviation Group, July 2002.

[72] When the Global Insight study examined the economics of improving the air transportation system, it used the more appropriate tools of benefit-cost analysis.

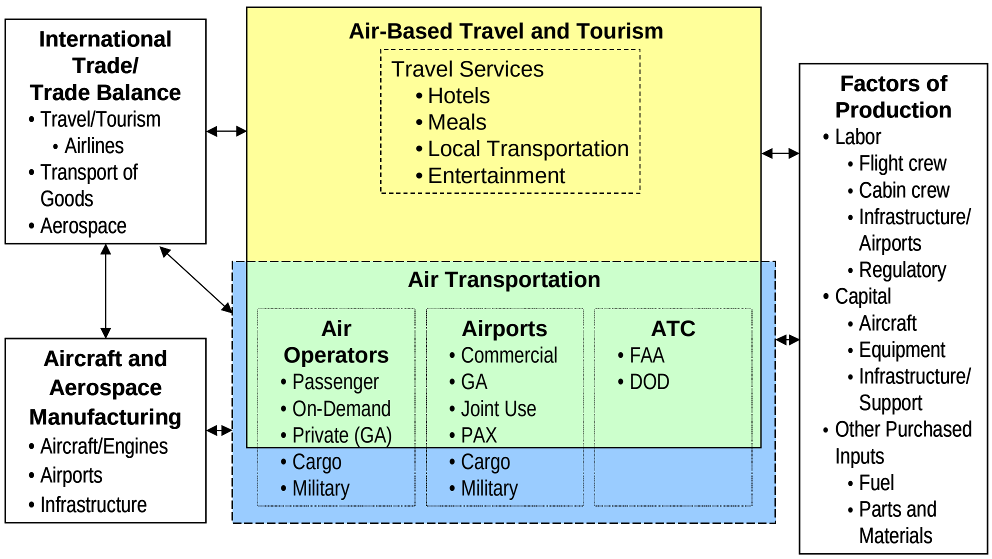
[73] *Final Report of the Commission on the Future of the United States Aerospace Industry*, November 2002, p. 1-2.

The following discussion presents numerous approaches to characterizing and quantifying these economic linkages between civil aviation and the broader economy. Figures 2-6 through 2-35 illustrate different approaches for characterizing and quantifying such economic connections between the air transportation industry and the broader economy.

Air Transportation and Other Industry Sectors

Figure 2-5 provides a general overview of connections and relationships between the air transportation industry and other parts of the economy. Aviation activity includes domestic and international operations, and commercial activity includes both cargo and passenger services. These services are used by passengers traveling for business or leisure purposes, or by shippers sending intermediate and final demand products to firms and individuals throughout the nation and the world.

Figure 2-5. Air Transportation and Other Industries/Industry Sectors



General aviation operators also provide passenger transport, and military aviation provides national defense and security services that affect all sectors of the economy.

Regardless of the specific nature and purpose of an air transportation operation, some mix of capital, labor and other inputs is necessary to produce it. This includes skilled labor services from a variety of professions, including pilots, cabin crews for passenger services, maintenance, logistics, airport and other infrastructure providers; and regulatory services and oversight. Labor services are also an essential input for the manufacture of aircraft, engines, and other aerospace products.

Aviation and aeronautics also play an important role in U.S. international trade, including trade in transportation services for both passengers and cargo and trade in aerospace goods, such as aircraft and engines. Taken together, the economic activity in these sectors make up the impact or share of the air transportation industry within the economy.

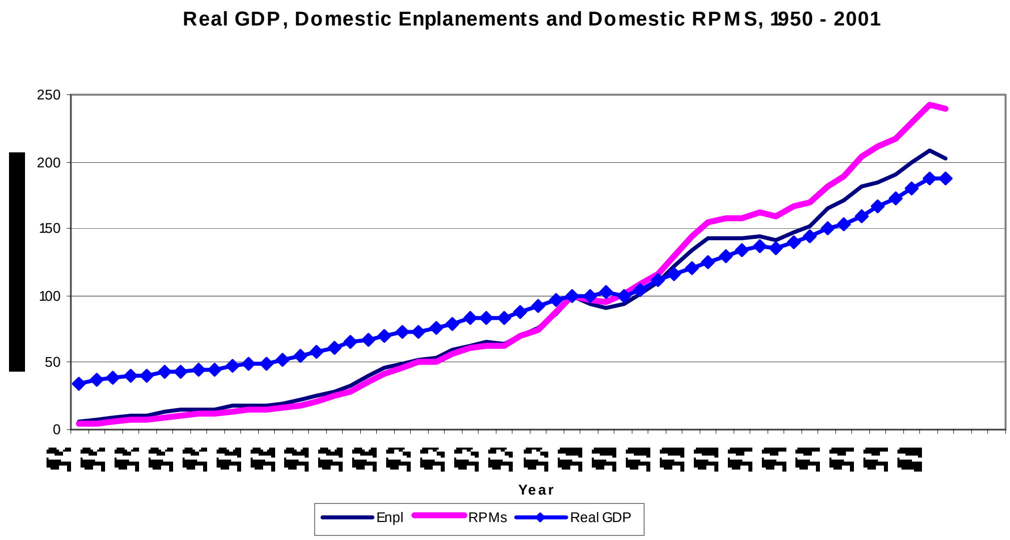
Demonstrating the Size of Air Transportation Industry Contributions Across the U.S. Economy

Historic data indicate close ties between growth in overall economic activity and growth in the air transportation sector. Domestic passenger aviation growth is closely related to changes in real GDP, and GDP growth induces growth in the demand for air transportation services—i.e., demand for air transportation is a “derived” demand.

Comparing Air Transportation Growth to Overall Economy

Figure 2-6 illustrates the relative growth of U.S. real GDP and domestic air carrier RPMs and enplanements from 1950 to 2001. The figure shows that the pace of growth of domestic passenger activity exceeded that for overall economic growth. This reflects both the steady fall in the real cost of air travel and the steady growth in U.S. per capita real income.

Figure 2-6. Relative Growth of U.S. Real GDP, Domestic Air Carrier RPMs, and Domestic Enplanements



Source: U.S. Department of Commerce, Bureau of Economic Analysis

GDP by Industry in Current Dollars

Figure 2-7 shows annual GDP by industry for all industries and for the air transportation industry from 1998 through 2001.[74] The GDP contribution of the air transportation industry ranges from $80 billion to $90 billion per year, or approximately 1% of GDP.

Figure 2-7. GDP by Industry in Current Dollars, 1998-2001 ($ Billions)

	1998	1999	2000	2001
All Industries	8,781.5	9,274.3	9,824.6	10,082.2
Transportation by air	85.8	90.0	91.9	80.2
Percent air	0.98%	0.97%	0.94%	0.80%

Source: Robert J. McCahill and Brian C. Moyer, "Gross Domestic Product by Industry for 1999-2001," Survey of Current Business, November 2002, p. 32.

Figure 2-8 presents annual gross output for all industries and for the air transportation industry for the same period. Gross output for the industry ranges from $135 billion to approximately $157 billion per year, or approximately 1% of the total gross output of all industries in the U.S. economy.

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[74] While gross output includes output of both intermediate goods and final goods and services, GDP includes goods and services produced for final sale only. Therefore, gross output exceeds GDP.

Figure 2-8. Gross Output by Industry, 1998-2001 ($ Billions)				
	1998	1999	2000	2001
All Industries	15,141.6	16,003.3	17,183.9	17,311.2
Transportation by Air	134.9	142.0	156.6	140.8
Percent Air	0.89%	0.89%	0.91%	0.81%

Source: Robert J. McCahill and Brian C. Moyer, "Gross Domestic Product by Industry for 1999-2001," Survey of Current Business, November 2002, p. 36.

Transportation Industry Value Added

Figure 2-9 shows the "value added" contribution of specific sectors of the transportation industry in 1997. (The value added of an industry is the total output of an industry less the value of purchased inputs.) [75] Value added by air transportation is the second largest among commercial modes. (In-house transportation is transportation provided by non-transportation companies that operate their own vehicles.) The Bureau of Transportation Statistics is currently working to provide measures of the use of in-house aircraft and air transportation services.[76]

Figure 2-9. Transportation Industry Value Added: 1997		
	1997	
	Value-Added	Percentage
In-house transportation	$157,765	38.3%
Motor freight and warehousing	$108,882	26.5%
Air transportation	$57,367	13.9%
Railroads and related services	$43,633	10.6%
Pipeline and related services	$25,859	6.3%
Water transportation	$17,884	4.3%
Total	$411,391	100.0%

"Total value added" equals total industry output less total intermediate inputs.

Source: Xiaoli Han and Bingsong Fang, "Four Measures of Transportation's Economic Importance," Journal of Transportation and Statistics, April 2000, p. 18.

Demonstrating the Breadth and Variety of Air Transportation Industry Contributions Across the U.S. Economy

The size of the air transportation industry's contribution to the overall economy is not the only important or informative measure of aviation's value. The breadth of the industry's presence across the economy is equally revealing. The following figures (Figures 2-10 through 2-28) illustrate important features of the air transportation system's place in the complex national economy, expressed in the diversity of economic sectors that rely in some way on its unique services.

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[75] Value added includes compensation of employees, indirect business tax and non-tax liability, consumption of fixed capital, net interest, proprietors' income, corporate profits, rental income of persons, business transfer payments, and subsidies less current surplus of government enterprises.

[76] Interview with Bureau of Transportation Statistics, September 25, 2003.

Air Transportation as an Industry Input

Figure 2-10 shows the use of air transportation by different industrial sectors. These data are for 1996, so while actual annual values may have increased, the SEDF study team assumes that the percentage distribution by industry is likely to have remained relatively stable over time. Manufacturing is the largest user of air transportation, followed closely by the services sector. Wholesale and retail trade and finance, insurance, real estate communications, and utilities are also relatively large users of air transportation.

Figure 2-10. Industries Using Air Transportation as an Input

Industry	Amount	**Percentage**
Manufacturing	$14,127	27.2%
Services	$11,665	22.5%
Air	$7,200	13.9%
Wholesale and retail trade	$6,092	11.7%
Finance, insurance, and real estate	$4,325	8.3%
Communications and utilities	$1,926	3.7%
Motor freight and warehousing	$1,843	3.5%
Other[1]	$1,783	3.4%
Construction	$1,227	2.4%
Agriculture, forestry, and fisheries	$695	1.3%
Mining	$425	0.8%
Railroad and passenger ground	$269	0.5%
Pipelines and freight forwarders	$259	0.5%
Water	$61	0.1%
Own-account transportation[1]	$14	0.0%
State and local passenger transit	$9	0.0%
Total intermediate inputs	**$51,919**	**100.0%**

The Transportation Satellite Accounts use of commodities by air transportation, 1996 ($millions at producers' prices).

Source: Bingsong Fang, Xiaoli Han, Sumiye Okubo, and Ann M. Lawson, "U.S. Transportation Satellite Accounts for 1996," Survey of Current Business, May 2000, p. 16.

1"Other" consists of government enterprises (except state and local government passenger transit) and other input-output (I-O) special industries. For a description of I-O special industries, see Ann M. Lawson, *Benchmark Input-Output Accounts for the U.S. Economy, 1992: Make, Use and Supplementary Tables,* Survey of current Business 77 (November 1997): 46-67.

Air Transportation as an Industry Output

Figure 2-11 shows the GDP contribution and total commodity output for the air transportation sector in 1996. This is comprised of the use of transportation by other industries that were described previously in Figure 2-10 as total intermediate inputs, and final uses such as those for personal consumption expenditures (vacation, visiting friends and relatives, etc.) and other categories. These final uses make up the GDP contribution measure of the air transportation industry. Costs associated with the use of air transportation as an intermediate input by other industries make up part of the output of final goods or services by those industries. The sum of an industry's provision of intermediate inputs to other sectors and its contribution to final demand for goods and services (GDP) represents the total output of an industry.

<table>
<tr><th colspan="4">Figure 2-11. Output of the Air Transportation Industry by National Accounts ($ Millions at Producers' Prices)</th></tr>
<tr><th></th><th>Amount</th><th>Distribution of Air Transportation's Contribution to GDP by National Accounts Category</th><th>Distribution of Air Transportation's Total Output, Including Intermediate Uses by Other Sectors</th></tr>
<tr><td>Personal consumption expenditures</td><td>$46,198</td><td>63.8%</td><td>37.2%</td></tr>
<tr><td>Gross private fixed investment</td><td>$2,320</td><td>3.2%</td><td>1.9%</td></tr>
<tr><td>Change in business inventories</td><td>$51</td><td>0.1%</td><td>0.0%</td></tr>
<tr><td>Exports of goods and services</td><td>$28,942</td><td>40.0%</td><td>23.3%</td></tr>
<tr><td>Imports of goods and services</td><td>($12,723)</td><td>-17.6%</td><td>-10.2%</td></tr>
<tr><td>Government expenditures</td><td>$7,637</td><td>10.5%</td><td>6.1%</td></tr>
<tr><td>Total GDP contribution</td><td>$72,425</td><td rowspan="3">100.0%</td><td>58.2%</td></tr>
<tr><td>Total intermediate inputs</td><td>$51,919</td><td>41.8%</td></tr>
<tr><td>Total commodity output</td><td>$124,344</td><td>100.0%</td></tr>
</table>

Source: Bingsong Fang, Xiaoli Han, Sumiye Okubo, and Ann M. Lawson, "U.S. Transportation Satellite Accounts for 1996," Survey of Current Business, May 2000, p. 16.

Travel and Tourism

The air transportation industry is a vital contributor to the travel and tourism industry. Overall, there were about $700 billion in tourism-related sales by the tourism industries in 2002. Figure 2-12 shows that air transportation accounts for approximately one-fourth of direct and indirect tourism-related sales in the tourism industry and accounted for more than $170 billion in 2002. As would be expected, the other big contributors to tourism industry output were hotels, lodging, restaurants, and bars.

Figure 2-12. Direct and Indirect Total Sales of Tourism-Related Sales of Tourism Industries, Fourth Quarter 2002 at an Annual Rate ($Billions)

Tourism Industry	Direct Tourism Sales	Indirect Sales in Other Industries	Direct and Indirect Tourism Sales	Percentage of Direct and Indirect Tourism Sales
Hotels and lodging places	110.6	87.3	197.9	27.9%
Air transportation	91.6	81.6	173.2	24.4%
Eating and drinking places	63.8	67.6	131.4	18.5%
Retail excluding restaurants and gas stations	32.2	18.0	50.3	7.1%
Automotive rental and leasing	23.2	22.7	45.9	6.5%
Amusement and recreation services	17.2	12.9	30.1	4.2%
Water transportation	9.3	10.6	20.0	2.8%
Motion pictures and other entertainment	8.9	6.7	15.6	2.2%
Membership sports and recreation clubs	6.3	4.7	11.0	1.5%
Gasoline service stations	3.3	6.0	9.3	1.3%
Taxicabs	5.0	3.8	8.7	1.2%
Travel agency services	3.6	2.8	6.4	0.9%
Local and bus passenger transit	2.4	1.8	4.3	0.6%
Professional sports clubs and promoters	2.0	1.5	3.6	0.5%
Railroads and related services	1.3	1.0	2.3	0.3%
All tourism industries	**380.8**	**329.1**	**709.8**	**100.0%**

Source: U.S. Bureau of Economic Analysis, Background on Tourism Satellite Accounts, http://www.bea.doc.gov./newsrel/tourbackground.htm

Tourism Demand by Commodity

Figure 2-13 shows tourism demand by commodity in 1997. This again shows that domestic and international passenger airfares total approximately one-quarter of total demand in the tourism sector. It is interesting to note that international airfares total about 40% of total airfares. This includes travel to and from the U.S. on both U.S. and foreign carriers. Travel and tourism accounts also show the share of spending by different types of visitors:

- Resident households in the United States accounted for 43% of total tourism expenditures
- The business sector accounted for 29%
- The government sector accounted for 5%

- Non-resident or international visitors accounted for 24%[77]

Figure 2-13. Tourism Demand by Commodity in 1997 ($Millions in Purchasers' Prices)		
Commodity	**1997 Tourism Demand**	**Percentage**
Hotels and lodging places	74,103	16.07%
Eating and drinking places	61,022	13.23%
Passenger rail	1,296	0.28%
Passenger bus and other local transportation	4,841	1.05%
Taxicabs	4,298	0.93%
Domestic passenger air fares	64,856	14.06%
International air fares	45,156	9.79%
Passenger water	4,384	0.95%
Auto and truck rental	21,092	4.57%
Other vehicle rental	485	0.11%
Arrangement of passenger transportation	3,766	0.82%
Recreation and entertainment	32,202	6.98%
Participant sports	5,311	1.15%
Movie, theater, ballet and musical events	6,511	1.41%
Sports events	1,763	0.38%
Travel by u.s. Residents abroad	53,451	11.59%
Gasoline and oil	14,371	3.12%
Personal consumption expenditure nondurable commodities other than gasoline and oil	52,745	11.44%
Parking, automotive repair, and highway tolls	9,514	2.06%
Total	**461,166**	**100.00%**

Source: David I. Kass and Sumiye Okubo, "U.S. Travel and Tourism Satellite Accounts for 1996 and 1997," Survey of Current Business, July 2000, p. 10.

Long Distance Trips

The role of air travel as a mode choice becomes more prominent as trip length increases. Figure 2-14 reports the percentage distribution of transport mode choices by U.S. households for long distance round trips of various lengths taken by members of U.S. households in 2001. Of round trips of 2000 miles or more in length, nearly 75% are traveled using air transportation, although relatively few long distance round trips of 500 or fewer miles are taken by air. This is related to the value placed on travel times and the tradeoff between time taken to travel (time-per-mile) and the cost of traveling (cost-per-mile).

Figure 2-14. Long Distance Trips in 2001						
Percent of Long-Distance Trips by Mode and Roundtrip Distance						
Miles	**100-299**	**300-499**	**500-999**	**1000-1999**	**2000+**	**Total**
Personal vehicle	97.2	94.3	85.9	53.9	22.2	89.5
Air	0.2	1.5	10.3	42.4	74.8	7.4
Bus*	1.6	3.4	3.2	2.6	1.4	2.1
Train*	0.9	0.7	0.6	0.9	0.8	0.8
Other*	0.2	0.1	0.0	0.1	0.8	0.2

Source: The 2001 National Household Travel Survey, preliminary long distance file, U.S. Department of Transportation.

[77] David I. Kass and Sumiye Okubo, "U.S. Travel and Tourism Satellite Accounts for 1996 and 1997," *Survey of Current Business*, July 2000, p. 10.

Trade Balance in Travel

International visitors to the United States contribute positively to the trade balance while the expenditures of U.S. travelers overseas reduce it. (Visitors to the U.S. from foreign countries bring money into the U.S. economy while U.S. residents who travel outside the country spend dollars outside the country.)

International visitors to the United States are an important component of the trade surplus. The trade surplus for tourism was $24.5 billion in 1997, almost one-third of the total trade surplus in services.[79] International visitors to the U.S. generated $96 billion in tourism demand.

Figure 2-15 shows a comparison of the trade balance in travel for 2001 and 2002. Exports of goods and services represent travel expenditures by foreign visitors to the U.S. and passenger fares paid to U.S. carriers by foreign visitors. Imports of goods and services represent travel expenditures by U.S. residents abroad as well as passenger airfares paid to foreign air carriers. Overall, the U.S. had a trade balance of approximately $7.5 billion in 2002 from travel.

Figure 2-15. U.S. International Transactions Year 2001 and Year 2002 ($Millions)

	2001	2002	Change: 2001-2002
Exports of Goods and Services and Income Receipts			
Travel	73,119	70,320	**-2,799**
Passenger fares	18,007	17,443	**-564**
Imports of Goods and Services and Income Receipts			
Travel	-60,117	-59,303	**814**
Passenger fares	-22,418	-20,993	**1,425**
Trade Balance			
Travel	13,002	11,017	**-1,985**
Passenger fares	-4,411	-3,550	**861**
Trade balance	8,591	7,467	-1,124

Source: U.S. Bureau of Economic Analysis,"U.S. International Transactions: Fourth Quarter and Year 2002, News Release BEA 03-07.

International Travel

Figure 2-16 shows the number of U.S. residents that traveled to a foreign country using air transportation in 2002. It also shows the number of foreign visitors who traveled to the U.S. by air. This is consistent with a positive trade balance in that more visitors came to the U.S. and spent more money per visitor than U.S. residents who traveled to a foreign country.

Figure 2-16. International Air Travel to and From the U.S. (2002)

	Millions
Foreign resident travel to the U.S.	24.6
U.S. resident travel to foreign countries	23.4

Source: U.S. Department of Commerce, Office of Travel and Tourism Industries, International Arrivals to the U.S. by Country of Residence, 2001. Includes all overseas arrivals plus arrivals by air from Canada and Mexico. Revised Estimates http://tinet.ita.doc.gov/view/f-2002-203-001; and 2001 Profile of U.S. Resident Traveler Visiting Overseas Destinations, Reported from: Survey of International Air Travelers, http://tinet.ita.doc.gov/view/f-2002-101-001.

[79] Ibid, p. 10.

Transportation of Goods

Figure 2-17 shows the overall movement of goods in the U.S. economy in 1997. Two things become apparent for the air transportation industry. It accounts for a negligible amount of the weight of goods shipped but it accounts for about 3.3% of the total value of all goods shipped in the U.S. economy. In addition, the average miles per shipment for air are larger than for any other mode. Due to the reporting conventions for the Commodity Flow Survey (which is the source for the data reported in Figure 2-17), the multiple mode of Parcel, U.S. Postal Service or Courier also may include air transportation.

Figure 2-17. Shipment Characteristics by Mode of Transportation for the U.S., 1997, All Goods Including Domestic

Mode of Transportation	Value		Tons		Ton-Miles		Average Miles Per Shipment
	Number ($Millions)	Percent	Number (Thousands)	Percent	Number (Thousands)	Percent	
Single Mode	5,719,558	82.4	10,436,538	94.1	2,383,473	89.6	184
- Truck[1]	4,981,531	71.7	7,700,675	69.4	1,023,506	38.5	144
- Rail	319,629	4.6	1,549,817	14.0	1,022,547	38.4	769
- Water	75,840	1.1	563,369	5.1	261,747	9.8	482
- Air (includes truck and air)	229,062	3.3	4,475	-	6,233	0.2	1,380
- Pipeline[2]	113,497	1.6	618,202	5.6	S	S	S
Multiple Modes	945,874	13.6	216,673	2.0	204,514	7.7	813
- Parcel, U.S. Postal Service, or courier	855,897	12.3	23,689	0.2	17,994	0.7	813
- Truck and rail	75,695	1.1	54,246	0.5	55,561	2.1	1,347
- Truck and water	8,241	0.1	33,215	0.3	34,767	1.3	1,265
- Rail and water	1,771	-	79,275	0.7	77,590	2.9	1,092
Other multiple modes	4,269	-	26,248	0.2	18,603	0.7	S
Other and unknown modes	278,555	4.0	436,521	3.9	73,376	2.8	122
All modes	**6,943,988**	**100.0**	**11,089,733**	**100.0**	**2,661,363**	**100.0**	**472**

Source: U.S. Census Bureau, 1997 Economic Census, Transportation 1997 Commodity Flow Survey, December 9, 1999, p. 9.

[1] "Truck as a single mode includes shipments that went by private truck only, for-hire truck only, or a combination of private trick and for-hire truck.

[2] CFS data for pipeline exclude most shipments of crude oil. See "Mileage Calculations" section for details of CFS coverage.

Growth Rates for Different Modes of Transportation

Figure 2-18 shows the relative growth of modes of transportation between 1993 and 1997 in terms of tonnage shipped. Again, while air transportation accounts for only a small proportion of the tonnage shipped, it had the highest growth rate of all single and multiple modes.

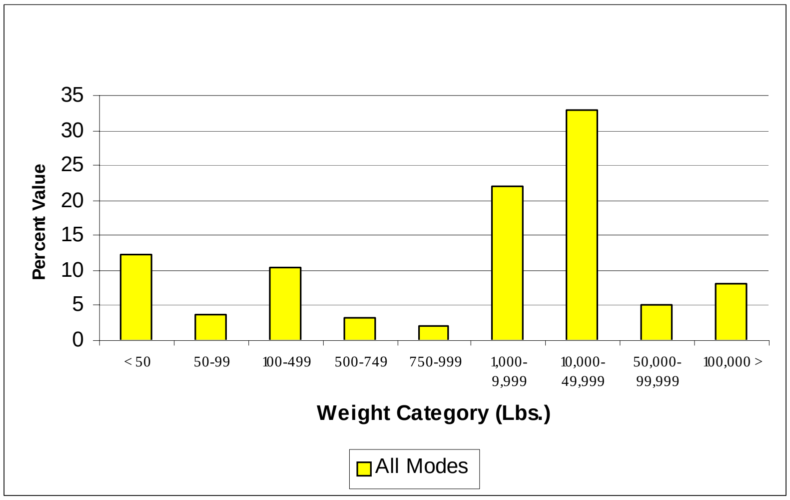
Figure 2-18. Shipment Characteristics by Mode of Transportation for the United States: 1997 and 1993			
Mode of Transportation	Tons		
	1997 (Thousands)	1993 (Thousands	Percent Change
All modes	11,089,733	9,688,493	14.5
Single mode	10,436,538	8,922,286	17.0
- Truck[1]	7,700,675	6,385,915	20.6
- Rail	1,549,817	1,544,148	0.4
- Pipeline[2]	618,202	483,645	27.8
- Water	563,369	505,440	11.5
- Air (includes truck and air)	4,475	3,139	42.6
Multiple modes	216,673	225,676	-4.0
- Rail and water	79,275	79,222	0.1
- Truck and rail	54,246	40,624	33.5
- Truck and water	33,215	67,995	-51.2
- Parcel, U.S. Postal service or courier	23,689	18,892	25.4
Other multiple modes	26,248	18,943	38.6
Other and unknown modes	436,521	540,530	-19.2

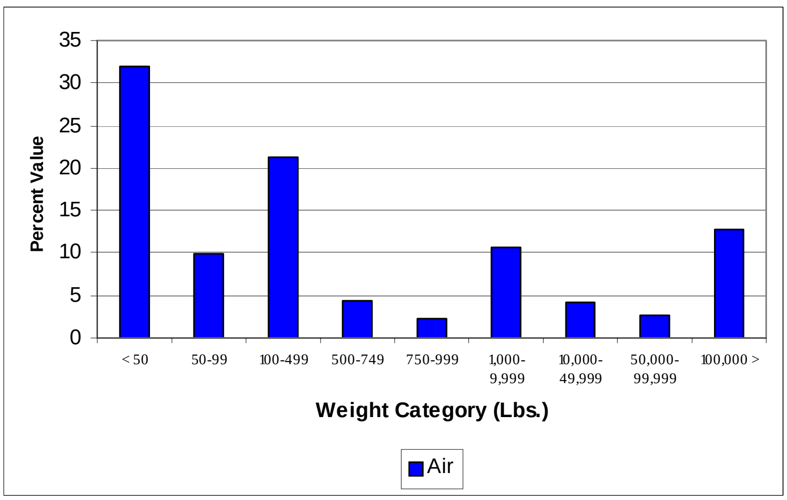
Source: Bingsong Fang, Xiaoli Han, Sumiye Okubo, and Ann M. Lawson, “U.S. Transportation Satellite Accounts for 1996,” Survey of Current Business, May 2000, p. 16.

Value by Shipment Size

Figure 2-19 shows the shipments by weight category for all modes, including shipments by air. As can be seen, shipments weighing less than 50 pounds comprise more than 30% of the value of all goods shipped by air.

Figure 2-19. Percentage Value of Goods Shipped by Shipment Size

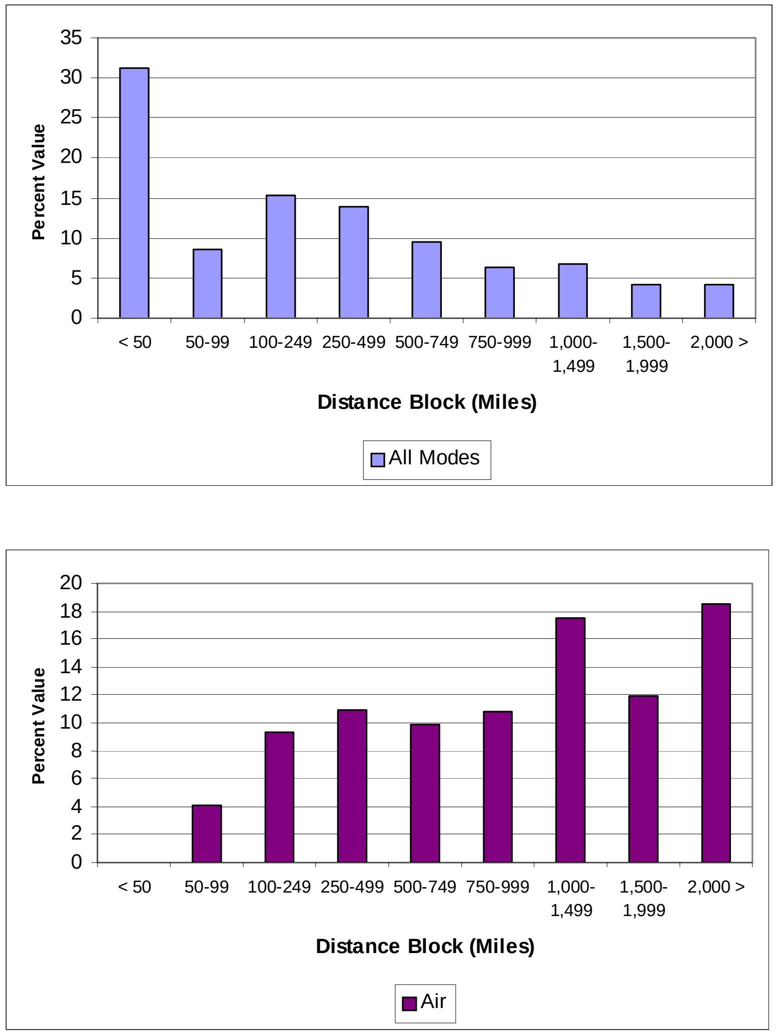




Value by Distance Shipped

Figure 2-20 shows the distance of shipments by percentage value of goods shipped. As can be seen, a large proportion of value of air shipments is concentrated in the longer distances (nearly 50% of the value of goods shipped by air is transported 1,000 miles or more). In contrast, a large proportion of the value of cargo shipped by all modes is concentrated in the shorter distances (nearly 70% by value is transported 499 miles or less).

Figure 2-20. Percentage Value of Goods Shipped by Shipment Distance



Air Transportation Across the Economy

The largest component of the demand for air transportation services falls within the national GDP accounts of final demand for goods and services. Air transportation is also used in most sectors of the economy. In these intermediate uses, air transportation delivers a wide variety of commodities and other inputs to intermediate and ultimately to final users of the goods and services that are delivered. The national economic input-output accounts maintained by the U.S. Department of Commerce Bureau of Economic Analysis (BEA) provide a detailed picture of the many users that rely on air transportation. While the most recently available data are from 1997, these data reveal an air transportation industry that is deeply enmeshed in the nation's economic structure.

Figure 2-21 contains a high level breakdown of all 1997 usage of air transportation services, as reported by BEA. The figure shows all final demand uses of air transport, intermediate uses of air transport to deliver goods and services to final demand purchasers, and intermediate uses of air transport within the "supply chain," delivering goods and services to intermediate users who add value to the product and sell into markets further downstream.

Figure 2-21. 1997 Users of Air Transport Services – Final Demand (GDP) and Distribution Uses (Millions of Dollars)

GDP (Final Demand) Accounts Millions of 1997$		
Personal consumption expenditures	$52,422	
Gross private investment	$2,519	
Changes in private inventories	$145	
Exports of goods and services	$30,591	
Imports of goods and services	($14,786)	
Federal government	$3,142	
State and local governments	$4,517	
Final demand (GDP) uses of air transport		$78,549
Air transport used for deliveries to final users		$10,428
Air transport used for deliveries to intermediate users		$9,106
Total		**$98,083**

Figure 2-21 shows the value of air transportation uses that fall within the seven national GDP accounts, including imports of air transportation services (use by U.S. entities of foreign air service providers), which takes a negative value. When exports of air transport services were adjusted for imports, U.S. net exports of air transport services in 1997 totaled $15.7 billion. Air transport services contributed $78.6 billion to 1997 GDP of $8.3 trillion, or nearly 1%. Further uses of air transport services include the delivery of goods and services to final demand uses ($10.4 billion in 1997) and intermediate delivery of goods and services to intermediate, value-adding producers ($9.1 billion in 1997). Thus, after adjusting for imports of air transport services, air transport services were valued at $98 billion in 1997. According to the BEA data, air transport service providers received revenues of $112.9 billion in 1997 ($98 billion adjusted for $14.8 billion in imports of air transport services). This is consistent with the 1997 total revenues of $109.6 billion reported to the DOT Office of Airline Services by U.S. air carriers.

While the overall magnitude of air transport service revenues is an important indicator of the place of air transport in the economy, it is also important to understand the value of air transport to users across the economic landscape. Information on this can be developed from disaggregated 1997 transport distribution cost data developed by the BEA.

Figures 2-22 through Figure 2-25 illustrate the breadth and variety of industries in the U.S. economy that rely on the air transportation industry for the movement of cargo and other services. For users of goods that are perishable or are high in value relative to their weight, the speed and ubiquity of air transportation offers unique value for inventory management and product reliability.

Air Transportation Costs by Commodity

Figure 2-22 shows 1997 air transport costs and other data for two digit standard industrial classification (SIC) commodity categories sorted by the ratio of air transport costs to the total purchase and delivery cost of the commodity to its users.

Figure 2-22. 1997 Two Digit SIC Code Commodity Groups Transported by Air to Intermediate and Final Users (Millions of 1997 Dollars

			Total G&S Value	Total Air Transport Costs	Total Transport Costs	Overall, Air Transport Cost to Value	Overall, Air Trans Cost to All Trans Cost	
			$23,022,751	$19,534	$214,556	0.1%	9.1%	
	SIC Code	Commodity Category	Value of G&S Used	Air Transport Costs	All Mode Transport Costs	Air Transport Cost to Total Value	Air Transport Cost to All Transport Cost	Air Transport Cost to Total Air Cost
1	2	Other agricultural products	$136,349	$2,096	$16,195	1.4%	12.9%	10.7%
2	51	Computer and office equipment	$98,123	$1,559	$1,673	1.6%	93.2%	8.0%
3	59	Motor vehicles (A & B)	$350,433	$1,349	$11,189	0.4%	12.1%	6.9%
4	60	Aircraft and parts	$102,433	$1,293	$1,409	1.2%	91.8%	6.6%
5	26	Newspapers and periodicals; Other printing and publishing	$122,689	$1,153	$3,898	0.9%	29.6%	5.9%
6	57	Electronic components and accessories	$143,250	$999	$1,068	0.7%	93.5%	5.1%
7	14	Food and kindred products	$485,921	$957	$17,953	0.2%	5.3%	4.9%
8	62	Scientific and controlling instruments	$123,806	$871	$1,082	0.7%	80.5%	4.5%
9	44 & 45	Farm, construction, and mining machinery	$53,075	$809	$2,799	1.4%	28.9%	4.1%
10	32	Rubber and miscellaneous plastics products	$156,843	$696	$13,812	0.4%	5.0%	3.6%
11	18	Apparel	$71,751	$678	$1,243	0.9%	54.6%	3.5%
12	47	Metalworking machinery and equipment	$40,374	$561	$979	1.4%	57.3%	2.9%
13	29	Drugs(A); Cleaning and toilet preparations(B)	$137,735	$485	$2,939	0.3%	16.5%	2.5%
14	56	Audio, video, and communication equipment	$89,145	$461	$1,023	0.5%	45.1%	2.4%
15	42	Other fabricated metal products	$78,094	$405	$2,864	0.5%	14.1%	2.1%
16	24	Paper and allied products, except containers	$114,078	$368	$10,853	0.3%	3.4%	1.9%
17	1	Livestock and livestock products	$100,418	$367	$1,058	0.4%	34.7%	1.9%
18	64	Miscellaneous manufacturing	$49,696	$359	$3,740	0.7%	9.6%	1.8%
19	49	General industrial machinery and equipment	$40,658	$358	$1,029	0.9%	34.8%	1.8%
20	53	Electrical industrial equipment and apparatus	$39,837	$335	$978	0.8%	34.3%	1.7%

The first row of the figure reports economy-wide values for air and other types of transport. In 1997, approximately $23 trillion in goods and services flowed through the productive sector of the economy. This total exceeds 1997 GDP of $8.3 trillion because it includes intermediate goods as well as final goods and services, and involves considerable double counting of goods as they move through the supply chain. Air transport services valued at $19.5 billion were used to deliver these goods to final and intermediate users within the economy.[80] The costs for moving goods and services using all available modes of transport were valued at $214.6 billion in 1997. Thus, the cost of air transport services used for moving goods and services was about 0.1% of the total cost (including transport) of the goods and services used in the economy. Within the intermediate transport sector, air transport represented 9.1% of total transport costs.

The table then shows the 20 commodity categories (out of 80) with the largest air transport dollar value associated with the cost of delivering it to intermediate or final users. The commodity category whose users called on the most air transport delivery services in 1997 was "other agricultural products" (which includes greenhouse and nursery products such as flowers). Final and intermediate users of these agricultural products spent $2.1 billion in 1997 for air transport services and $16.2 billion for all transport services. These expenditures supported the movement of commodities valued at $136.3 billion. Within this commodity category, the cost of air transport services called upon by commodity users represented 1.4% of the total cost of these commodities (including transport costs), 12.9% of all transport costs used within this commodity category, and 10.7% of all air transport services used to transport intermediate and final goods within the economy. Other prominent commodity categories in terms of air transportation use included computer equipment and parts, motor vehicle and aircraft parts and components, and electronic components.

Commodities Associated with Air Transportation

Depending on the weight, value, and perishability of a commodity, and on the needs of the user, the speed and immediacy of delivery by air has greater or lesser value. In some cases, users of a commodity obtain it almost exclusively by air transportation, and in other cases, other modes are always used. Figure 2-23 reports 1997 commodity categories by the predominance with which air transport is chosen as a preferred form of transport. The 20 commodity categories with the highest ratios of air transport delivery costs to total delivery costs are shown. Amusements (which includes films) require only modest amounts of transport services, but air transport is the only mode chosen. Five commodity categories—electronic components; computer/office equipment; aircraft and parts; forestry/fishery products; and scientific/controlling instruments— rely on air transport for over 80% of their overall transport costs. These tend to be commodities that are light, of high value, and/or perishable.

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[80] Intermediate users are those industries that use the commodity (good or service) as input for producing a good or service. For example, computer manufacturers may purchase semiconductor parts to include in a computer, which in turn is made available for sale to final users. Final users are consumers making consumption purchases, businesses making investment purchases, or governments making purchases. For example, members of any of these groups may purchase semiconductors for its own needs. In 1997, intermediate transport costs for delivery to intermediate users totaled $9.1 billion, with the remainder of intermediate transport costs—$10.5 billion—accruing to delivery of final goods and services.

Figure 2-23. 1997 Commodity Categories Transported by Air to Intermediate and Final Users, by Ratio of Air Transport Costs to Cost of All Transport Services for that Category (Millions of 1997 Dollars)

Total G&S Value	Total Air Transport Costs	Total Transport Costs	Overall, Air Transport Cost to Value	Overall, Air Trans Cost to All Trans Cost
$23,022,751	$19,534	$214,556	0.1%	9.1%

	SIC Code	Commodity Category	Value of G&S Used	Air Transport Costs	All Mode Transport Costs	Air Transport Cost to Total Value	Air Transport Cost to All Transport Cost	Air Transport Cost to Total Air Cost
1	76	Amusements	$190,881	$4	$4	0.0%	100.0%	0.0%
2	57	Electronic components and accessories	$143,250	$999	$1,068	0.7%	93.5%	5.1%
3	51	Computer and office equipment	$98,123	$1,559	$1,673	1.6%	93.2%	8.0%
4	60	Aircraft and parts	$102,433	$1,293	$1,409	1.2%	91.8%	6.6%
5	3	Forestry and fishery products	$14,925	$202	$234	1.3%	86.3%	1.0%
6	62	Scientific and controlling instruments	$123,806	$871	$1,082	0.7%	80.5%	4.5%
7	47	Metalworking machinery and equipment	$40,374	$561	$979	1.4%	57.3%	2.9%
8	73	Professional services	$1,363,911	$18	$31	0.0%	55.7%	0.1%
9	18	Apparel	$71,751	$678	$1,243	0.9%	54.6%	3.5%
10	48	Special industry machinery and equipment	$33,615	$333	$712	1.0%	46.7%	1.7%
11	56	Audio, video, and communication equipment	$89,145	$461	$1,023	0.5%	45.1%	2.4%
12	19	Miscellaneous fabricated textile products	$27,251	$131	$312	0.5%	42.1%	0.7%
13	41	Screw machine products and stampings	$52,689	$254	$713	0.5%	35.6%	1.3%
14	49	General industrial machinery and equipment	$40,658	$358	$1,029	0.9%	34.8%	1.8%
15	1	Livestock and livestock products	$100,418	$367	$1,058	0.4%	34.7%	1.9%
16	53	Electrical industrial equipment and apparatus	$39,837	$335	$978	0.8%	34.3%	1.7%
17	43	Engines and turbines	$24,588	$153	$474	0.6%	32.2%	0.8%
18	26	Newspapers and periodicals; Other printing and publishing	$122,689	$1,153	$3,898	0.9%	29.6%	5.9%
19	44 & 45	Farm, construction, and mining machinery	$53,075	$809	$2,799	1.4%	28.9%	4.1%
20	63	Ophthalmic and photographic equipment	$22,644	$83	$291	0.4%	28.6%	0.4%

Greatest Users of Air Transportation

Previous figures reported 1997 air transport patterns selected by users of specific commodity categories at the two-digit SIC level. Using the commodity used/industry using data, it is also possible to present air transport utilization patterns chosen by specific industry groupings for intermediate delivery of the full range of goods and services they use. Figure 2-24 reports the 20 industry groupings (at the 1997 two-digit SIC code level) that are the greatest users of air transport for delivery of input commodities. The figure is similar to those above, reporting the value of goods and services required by each of the industry groupings for use in intermediate production, the cost of air transportation used by the grouping, the cost of all transport services used by the grouping, and ratios associated with these values for each industry grouping. Because these data include only intermediate uses of goods and services, the total of air transportation used sums to $9.1 billion for 1997. The greatest users of air transport for delivery of input commodities were the motor vehicles industry, industries producing food and kindred products, and those producing agricultural, forestry and fishery services.

Figure 2-24. Industries (at Two Digit SIC Code) Using Air Transport for Delivery of Input Commodities in 1997, by Cost of Air Transport Services Used (Millions of 1997 Dollars)

	Total G&S Value	Total Air Transport Costs	Total Transport Costs	Overall, Air Transport Cost to Value	Overall, Air Trans Cost to All Trans Cost
	$13,760,898	$9,106	$146,060	0.1%	6.2%

	SIC Code	Commodity Category	Value of G&S Used	Air Transport Costs	All Mode Transport Costs	Air Transport Cost to Total Value	Air Transport Cost to All Transport Cost	Air Transport Cost to Total Air Cost
1	59	Motor vehicles (A & B)	$351,311	$1,250	$6,808	0.3%	18.4%	13.7%
2	14	Food and kindred products	$486,269	$624	$11,604	0.1%	5.4%	6.9%
3	4	Agricultural, forestry, and fishery services	$40,987	$544	$935	1.3%	58.1%	6.0%
4	60	Aircraft and parts	$101,818	$504	$934	0.5%	54.0%	5.5%
5	73	Professional services	$1,233,141	$480	$1,871	0.0%	25.7%	5.3%
6	11	New construction	$640,725	$460	$10,918	0.1%	4.2%	5.0%
7	77	Health, education and social services	$1,029,919	$340	$3,179	0.0%	10.7%	3.7%
8	74	Eating and drinking places	$356,886	$302	$3,225	0.1%	9.4%	3.3%
9	51	Computer and office equipment	$103,302	$294	$477	0.3%	61.7%	3.2%
10	75	Automotive repair and services	$196,709	$294	$1,507	0.1%	19.5%	3.2%
11	69	Wholesale and Retail Trade	$1,495,287	$217	$2,550	0.0%	8.5%	2.4%
12	57	Electronic components and accessories	$138,426	$199	$907	0.1%	22.0%	2.2%
13	26	Newspapers and periodicals; Other printing and publishing	$207,517	$191	$3,377	0.1%	5.6%	2.1%
14	12	Maintenance and repair construction	$303,583	$189	$5,335	0.1%	3.5%	2.1%
15	65	Transportation (passenger and freight)	$504,654	$179	$2,851	0.0%	6.3%	2.0%
16	56	Audio, video, and communication equipment	$88,025	$160	$452	0.2%	35.5%	1.8%
17	62	Scientific and controlling instruments	$123,167	$147	$678	0.1%	21.7%	1.6%
18	2	Other agricultural products	$142,439	$139	$1,781	0.1%	7.8%	1.5%
19	18	Apparel	$72,710	$131	$903	0.2%	14.5%	1.4%
20	37	Primary iron and steel manufacturing	$105,002	$116	$4,615	0.1%	2.5%	1.3%

Major Users of Air Transportation

As with specific commodity groupings, some industry groupings use air transportation with greater frequency. Figure 2-25 reports a comparison of industry groupings on this basis. Three industry groupings spend more than half of their transportation dollars on air: 1) computer and office equipment; 2) agriculture, forestry, and fishery services; and 3) aircraft and parts.

Figure 2-25. Industries (at Two Digit SIC Code) Using Air Transport for Delivery of Input Commodities in 1997, by Ratio of Air Transport Costs to Total Transport Costs Used by Industry (Millions of 1997 Dollars)

			Total G&S Value	Total Air Transport Costs	Total Transport Costs	Overall, Air Transport Cost to Value	Overall, Air Trans Cost to All Trans Cost	
			$13,760,898	$9,106	$146,060	0.1%	6.2%	
	SIC Code	Commodity Category	Value of G&S Used	Air Transport Costs	All Mode Transport Costs	Air Transport Cost to Total Value	Air Transport Cost to All Transport Cost	Air Transport Cost to Total Air Cost
1	51	Computer and office equipment	$103,302	$294	$477	0.3%	61.7%	3.2%
2	4	Agricultural, forestry, and fishery services	$40,987	$544	$935	1.3%	58.1%	6.0%
3	60	Aircraft and parts	$101,818	$504	$934	0.5%	54.0%	5.5%
4	66	Communications, except radio and TV	$319,092	$101	$273	0.0%	36.8%	1.1%
5	56	Audio, video, and communication equipment	$88,025	$160	$452	0.2%	35.5%	1.8%
6	13	Ordnance and accessories	$20,041	$56	$164	0.3%	34.0%	0.6%
7	73	Professional services	$1,233,141	$480	$1,871	0.0%	25.7%	5.3%
8	57	Electronic components and accessories	$138,426	$199	$907	0.1%	22.0%	2.2%
9	62	Scientific and controlling instruments	$123,167	$147	$678	0.1%	21.7%	1.6%
10	67	Radio and TV broadcasting	$41,362	$3	$14	0.0%	19.7%	0.0%
11	75	Automotive repair and services	$196,709	$294	$1,507	0.1%	19.5%	3.2%
12	59	Motor vehicles (A & B)	$351,311	$1,250	$6,808	0.3%	18.4%	13.7%
13	48	Special industry machinery and equipment	$33,992	$60	$367	0.2%	16.2%	0.7%
14	49	General industrial machinery and equipment	$41,798	$64	$409	0.2%	15.7%	0.7%
15	52	Service industry machinery	$38,453	$64	$434	0.2%	14.6%	0.7%
16	76	Amusements	$188,718	$52	$357	0.0%	14.5%	0.6%
17	18	Apparel	$72,710	$131	$903	0.2%	14.5%	1.4%
18	3	Forestry and fishery products	$11,327	$7	$52	0.1%	13.2%	0.1%
19	53	Electrical industrial equipment and apparatus	$39,167	$59	$448	0.1%	13.1%	0.6%
20	33 & 34	Footwear, leather, and leather products	$9,132	$21	$173	0.2%	12.4%	0.2%

Import-Export Shipment Data

Air transportation plays a much larger role in international trade than in the domestic economy. In part, this reflects the distance over which imports and exports travel. It also reflects the type of goods shipped. Figure 2-26 shows the total imports and exports of merchandise goods by value and weight in 2002.[81] Air accounts for a negligible percentage of total shipments by weight. However, it accounts for 30% - 50% of merchandise imports and exports by value. Clearly, air is the preferred mode of shipment for high valued goods.

Figure 2-26. Total Imports/Exports of Merchandise: Value and Weight ($millions; weight in pounds millions)

	Total Weight	Weight by Air	Percentage Air Weight	Total Value	Total Value by Air	Percentage Air Value	Value by Pound Air
Imports	817,418	3,557	0.44%	$811,241	$273,176	34%	$77
Exports	316,913	2,118	0.67%	$378,462	$195,040	52%	$92
Total	**1,134,332**	**5,675**	**0.50%**	**$1,189,703**	**$468,216**	**39%**	**$83**

Source: U.S. Department of Commerce, U.S. Imports and Exports of Merchandise 2002, February 2003.

Main Exports Transported by Air

Figure 2-27 shows the top exports by commodity and air value in 2002. As can be seen, the principal exports that move by air include electrical machinery, data processing equipment, instruments, aerospace parts, and medicines.

Figure 2-27. Merchandise Exports Year 2002

Import Harmonized Code and Commodity Description	Air Weight (Millions of Pounds)	Air Value ($Millions)
Electrical machinery and equipment and parts thereof	229.5	$55,772.2
Data processing and other office machines; turbojets, turbopropellers and other gas turbines	457.1	$52,065.2
Instruments and appliances used in medical, surgical, dental or veterinary sciences; measuring devices	145.6	$28,057.6
Powered aircraft; spacecraft (including satellites); spacecraft launch vehicles; and parts thereof	44.2	$13,661.9
Medicaments for therapeutic use	45.8	$9,726.9
Gold, jewelry of precious metal, waste and scrap of precious metal, diamonds	7.1	$7,295.7
Organic chemicals (cyclic hydrocarbons; antibiotics, etc.)	35.9	$4,204.4
Miscellaneous chemical products (diagnostic or laboratory reagents, insecticides, reaction initiators, etc.)	75.7	$3,307.1
Plastics and articles thereof (used for packing of goods, tableware, household articles, etc.)	11.1	$2,059.9
Motor cars and other motor vehicles designed to transport people and goods and parts thereof	54.1	$1,603.2
Printed books, brochures, leaflets, newspapers, etc.	46.7	$1,191.7

Source: U.S. Department of Commerce, U.S. Imports, and Exports of Merchandise 2002, February 2003

High Value Goods Shipped by Air

Figure 2-28 shows data on the types of merchandise imports ranked by value shipped by air. Again, electrical machinery and data processing equipment account for the largest groups by value of imported goods. Diamonds and jewelry, organic chemicals, and medical or surgical instruments also account for large shares of U.S. merchandise imports shipped by air.

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[81] Merchandise goods exclude the shipment of commodities.

Figure 2-28. Merchandise Imports Year 2002		
Import Harmonized Code and Commodity Description	**Air Weight (millions of pounds)**	**Air Value ($millions**
Electrical machinery and equipment and parts thereof	533.6	$64,824.8
Data processing and other office machines	652.7	$61,827.0
Diamonds, jewelry of precious metal, platinum	23.0	$22,831.1
Organic chemicals	31.1	$21,861.7
Medical or surgical instruments and apparatus	151.1	$20,203.6
U.S. goods returned after being exported	76.5	$18,747.2
Medicaments for therapeutic use	38.9	$17,517.2
Articles of apparel and clothing accessories, not knitted or crocheted	257.2	$6,587.8
Articles of apparel and clothing accessories, knitted or crocheted	236.6	$4,648.8
Works of art (paintings, drawings and pastels) and antiques	6.0	$4,272.4
Powered aircraft; spacecraft (including satellites); spacecraft launch vehicles; and parts thereof	8.1	$3,950.4
Watches (wrist, pocket and other); clocks; alarms	13.7	$2,212.1

Source: U.S. Department of Commerce, U.S. Imports and Exports of Merchandise 2002, February 2003.

Air Transportation Sector Employment

The air transportation sector supported more than 873,000 jobs in 1997, the year of the most recent economic census. Large certificated air carriers represented the largest employer, followed by other air transportation, airport operations, and other support activities, as shown in Figure 2-29. Data do not reflect employment in private aviation, industries that supply the air transportation industry, or FAA employees that modernize, operate, and maintain the air traffic control system.

Figure 2-29. Employment in the Air Transportation Sector (1997 Data)	
Airport operations - Air traffic control - Other airport operations	62,138 502 61,636
Other support activities for air transportation	53,318
Flight training	12,260
Large certificated carriers	656,243
Air transportation—all others - Scheduled air transportation - Nonscheduled air transportation	89,125 65,988 23,137
Total	**873,084**

Sources: 1. http://www.census.gov/epcd/ec97/us/US000_48.HTM and 2. http://www.bts.gov/oai/employees/1997emp.html

Other Measures

Airports also comprise a significant portion of the air transportation industry. Figure 2-30 shows 2001 financial data for 514 airports as reported to the FAA by airports with commercial service (with at least 2,500 annual enplanements). Airports reported about $14.5 billion in revenues and reported about $11 billion in expenses.

Figure 2-30. Financial Summary Commercial Service Airports (FY 2001 $Billions)	
Revenues	
Aeronautical operating revenue	$5.3
Non-aeronautical operating revenue	$4.7
Non-operating revenue	$4.5
Total revenues	$14.5
Expenses	
Operating expenses	$6.2
Non-operating expenses	$2.7
Depreciation	$2.4
Total expenses	$11.3
Net revenues less expenses	$3.2

Source: FAA Form 5100-127, Operating and Financial Summary for Airports with Commercial Service.

The FAA also provides funds for airport and air traffic control capacity as well as for the operation of the air traffic control system. Figure 2-31 provides a summary of the FAA budget for FY 2002 and related financial data. Overall, the budget was approximately $13.5 billion. Approximately $9 billion was raised from user taxes and fees paid by passengers, shippers, air carriers, and general aviation. These proceeds are placed in the Airport and Airway Trust Fund. In FY 2002, $12.7 billion was taken from the trust fund to support FAA programs.

FAA disbursements for airport grants were about $3.2 billion. In part, these airport grants are reflected in Figure 2-31. Nearly all of the remainder of FAA's budget is for investment in or operations of facilities and equipment, and maintenance of the NAS. In all, FAA invests about $6 billion in the air transportation system annually between airports and the NAS.

Figure 2-31. FAA FY 202 Budget and Trust Fund

FAA Programs	Budgets ($Millions)
Airport Improvement Program	$3,173
Facilities and Equipment (F&E)	$3,006
Research, Engineering and Development (R,E&D)	$245
Operations and Maintenance (O&M)	$7,076
Total	**$13,500**
Other Data	
Total tax and fee revenue	$9,031
Trust fund interest	$860
FAA budget from trust fund	$12,699

Aircraft Manufacturing Impacts

Civil aircraft manufacturing is an important component of the air transportation industry in the United States. Figure 2-32 shows the sales of civil aircraft, engines, and parts from 1987 to 2001. 2001 sales totaled $52.7 billion.

Figure 2-32. Sales of Civil Aircraft, Engines, and Parts, Calendar Years 1987-2001 ($millions)

Non-Military, Current Dollars			
Year	Total	Complete Aircraft and Parts	Aircraft Engines and Parts
1987	$21,256	$14,862	$6,394
1988	$25,674	$16,681	$8,993
1989	$29,538	$20,140	$9,398
1990	$38,622	$27,872	$10,750
1991	$43,155	$33,215	$9,940
1992	$44,160	$35,595	$8,565
1993	$40,987	$32,780	$8,207
1994	$30,901	$23,176	$7,725
1995	$32,085	$22,897	$9,188
1996	$32,722	$20,993	$11,729
1997	$42,614	$33,206	$9,408
1998	$52,708	$42,541	$10,167
1999	$56,406	$45,107	$11,299
2000[r]	$46,477	$37,538	$8,939
2001	$52,768	$40,812	$11,956

Source: Bureau of the Census, "Aerospace Industry (Orders, Sales and Backlog)" Series MA37D (Annually). (Data taken from Aerospace Facts and Figures 2002/2003, p. 26)

rRevised.

Figure 2-33 shows the distribution of aircraft sales by type for the 1987 to 2001 period. Transport aircraft accounted for $34.2 billion, helicopters $247 million, and GA $8 billion in 2001. Largest growth occurred in the general air transportation industry sector.

Figure 2-33. Civil Aircraft Shipments, Calendar Years 1987-2001

Value - Millions of Dollars				
Year	Total	Transport Aircraft[a]	Helicopters	General Aviation
1987	$12,148	$10,507	$277	$1,364
1988	$15,855	$13,603	$334	$1,918
1989	$17,129	$15,074	$251	$1,804
1990	$24,477	$22,215	$254	$2,008
1991	$29,035	$26,856	$211	$1,968
1992	$30,728	$28,750	$142	$1,836
1993	$26,389	$24,133	$113	$2,144
1994	$20,666	$18,124 [E]	$185	$2,357
1995	$18,299	$15,263 [E]	$194	$2,842
1996	$20,805	$17,564 [E]	$193	$3,048
1997	$31,753	$26,929	$231	$4,593
1998	$41,449	$35,663	$252	$5,534
1999	$45,161	$38,171	$187	$6,803
2000	$38,637	$30,327	$270	$8,040
2001	$42,399	$34,155	$247	$7,997

Source: Aerospace Industries Association, based on company reports and General Aviation Manufacturers' Association. (Data taken from Aerospace Facts and Figures 2002/2003, p. 30)

a U.S.-manufactured fixed-wing aircraft over 33,000 pounds empty weight, including all jet transports plus the four-engine turboprop-powered Lockheed L-100.

E Estimated.

International Trade in Aircraft

The U.S. is both an importer and exporter of aircraft, engines, and parts. Figure 2-34 presents import and export data for the aircraft industry from 1998 to 2001. The U.S. had a trade surplus overall of $23.7 billion in 2001. However, the trend has been declining, where most of the decline in the trade balance was for complete aircraft.

Figure 2-34. U.S. Exports and Imports of Aircraft Products and Trade Balance, Calendar Years 1998-2001 ($Millions)

	1998	1999	2000	2001
Aircraft Exports				
Civil Total	$51,999	$50,624	$45,566	$49,371
Complete Aircraft	$31,427	$28,450	$22,156	$24,787
Aircraft Engines	$3,158	$3,714	$4,610	$5,258
Aircraft and Engine Parts Including Spares	$16,744	$18,051	$18,660	$19,169
Aircraft Imports				
Civil Total	$16,837	$18,709	$21,994	$25,670
Complete Aircraft	$6,933	$8,773	$12,388	$14,709
Aircraft Engines	$2,039	$2,257	$1,864	$2,418
Aircraft and Engine Parts	$7,866	$7,680	$7,742	$8,543
Difference of Aircraft Exports and Imports (Trade Balance)				
Civil Total	$35,162	$31,915	$23,572	$23,701
Complete Aircraft	$24,494	$19,677	$9,768	$10,078
Aircraft Engines	$1,119	$1,457	$2,746	$2,840
Aircraft Engine Parts Including Spares	$8,878	$10,371	$10,918	$10,626

Source: Aerospace Industries Association, based on data from International Trade Administration. (Data taken from Aerospace Facts and Figures 2002/2003, pp. 120-121)

Employment

Figure 2-35 shows employment trends in the aircraft and related industries. Data include employment in both civil and military aircraft programs. Employment steadily declined after 1990, falling by more than 35% from 1990-2001.

Figure 2-35. Employment in the Aerospace Industry[a], Calendar Years 1987-2001 (Annual Average, Thousands of Employees)

Total Employment						
Year	**Airframes (SIC 3721)**	**Engines and Parts (SIC 3724)**	**Other Parts and Equipment (SIC 3728)**	**Sub-Total (SIC 372)**	**Other[b]**	**Total**
1987	356	158	163	678	399	1,077
1988	369	156	159	684	402	1,086
1989	382	154	175	711	408	1,119
1990	381	152	180	712	405	1,117
1991	356	143	170	669	378	1,047
1992	332	127	153	612	342	954
1993	301	109	131	542	300	842
1994	271	95	115	482	266	748
1995	244	93	114	451	248	699
1996	243	95	120	458	248	706
1997	262	100	138	501	267	768
1998	272	103	150	525	279	804
1999	254	101	141	496	263	759
2000[r]	234	101	130	464	248	712
2001	233	99	129	461	246	707

Source: Bureau of Labor Statistics, "Employment and Earnings" (Monthly) and Aerospace Industries Association estimates. (Data taken from Aerospace Facts and Figures 2002/2003, pp. 140-141--includes employment for both civil and military production.)

a Annual average calculated as one-twelfth of sum of monthly estimates of total number of persons employed during a designated pay period by the aircraft (SIC 372).

b Communications, navigation, flight control and displays (aerospace-related portions of SICs 366, 381 and 382.

rRevised.

E S T I M A T I N G T H E V A L U E O F T R A N S F O R M A T I O N

The SEDF approach to assessing economic risk to the nation of allowing NAS capacity to fall short of accommodating future demand provides an estimate of the impact and size of a projected shortfall between demand and capacity in 2015 and 2025. Factors contributing to this risk include:

- Extent and cost of embedded delays
- Number of trips foregone by passengers unable to fly (unmet demand)
- Increased airline operating costs resulting from delay
- Size of fare increases
- Increased passenger time lost to delay

ESTIMATING THE COST OF EMBEDDED DELAY

Inefficiencies embedded within the current air transportation system create delay and cost billions of dollars annually. One area of inefficiency derives from delay that airlines build into their schedules. Two underlying effects may provide incentives to embed delay into the schedules. First, carriers may legitimately add time to account for expected delays on particular flights (the “delay” effect)—e.g., if the 8 o’clock hour at O’Hare is always congested, a carrier that wants to offer a departure at 8:30 may add minutes to the scheduled arrival time in order to accommodate the congestion and expected delay. Secondly, DOT’s widely distributed On-Time Performance Reports, which publicize the number of flights with actual flight times that exceed the airlines’ published schedule times by 15 minutes or more, may provide the airlines with an incentive to pad their schedules further so that more flights are considered on-time (the “schedule creep” effect). It is important to recognize these underlying effects in any analysis of embedded delay.

Using the model described in Appendix D, estimates can be generated for the schedule times that would occur if embedded delays were reduced to zero; this is done by computing the predicted schedule times with and without the delay variables, and taking the difference between the two predictions. Aggregating over all flights, we then can compute average time-savings per flight. Such time savings (on the order of 3 to 4 minutes per flight) can be converted into total dollar savings to carriers and consumers by applying estimates of average values for load factors, aircraft variable operating costs, and passenger value of time. These are estimated to be increased aircraft delay of about 650,000 hours per year and embedded passenger delay of approximately 43 million hours. The total economic cost of embedded delay is estimated to be approximately $3.3 billion in 2000, as shown in Figure 2-36.

Figure 2.36. Estimated Impact of Embedded Schedule Delay (Based on Continental U.S. Only)					
	2000 Q1	2000 Q2	2000 Q3	2000 Q4	Year 2000
Total flights	2,571,537	2,574,322	2,643,319	2,674,059	10,463,237
Average seat size of all flights	92	93	92	93	
Predicted average delay per flight	2.84	3.56	4.35	4.07	
Aircraft minutes of delay	7,302,111	9,175,222	11,497,417	10,874,000	38,848,750
Aircraft hours of delay	121,702	152,920	191,624	181,233	647,479
Passenger delay in minutes (LF 71.2%)	479,877,201	604,933,415	754,764,007	720,807,026	2,560,381,649
Passenger delay hours	7,997,953	10,082,224	12,579,400	12,013,450	42,673,027
Aircraft delay cost (2 Eng NB cost inflated at 3%)	$398,891,662	$501,213,927	$628,068,197	$594,012,895	$2,122,186,681
Passenger delay cost ($26.70 per hour)	$228,741,466	$288,351,595	$359,770,843	$343,584,682	$1,220,448,586
Total cost	**$627,633,128**	**$789,565,522**	**$987,839,040**	**$937,597,577**	**$3,342,635,267**

Assessing a Shortfall Between Demand and Capacity

There is inherent uncertainty about how a capacity constrained air transportation system will evolve over the next 20 years. However, reliable estimates of the economic cost of a future air transportation system that lacks sufficient capacity to meet demand can help policy makers and planners understand the importance of acting now to prevent a significant shortfall. In response to that need, the following discussion models differences between future air transportation sectors with, and without, capacity constraints, then estimates the economic costs for consumers and others of a projected NAS capacity shortfall.

Consumer Surplus

The economic concept of "consumer surplus" is an important conceptual tool for valuing the loss to air travelers from a future NAS capacity shortfall. In the marketplace, the interaction of buyers and sellers determines the market-clearing price. The demand curve for a good or service represents the marginal benefit received by the purchaser of each additional unit of the good or service, as measured by the amount a buyer is willing to pay for it.

Buyers who pay the market clearing price for a particular good or service—but who would be willing to pay more, if necessary (inframarginal buyers)—in effect enjoy a bonus, since they acquire the good or service for less than they were willing to pay. This bonus, aggregated over all consumers able to purchase at a price lower than what they are willing to pay is termed "consumer surplus." It measures the total value received by buyers from obtaining and consuming a good or service that is in excess of the total amount of money that is spent by the buyers to obtain the good or service.

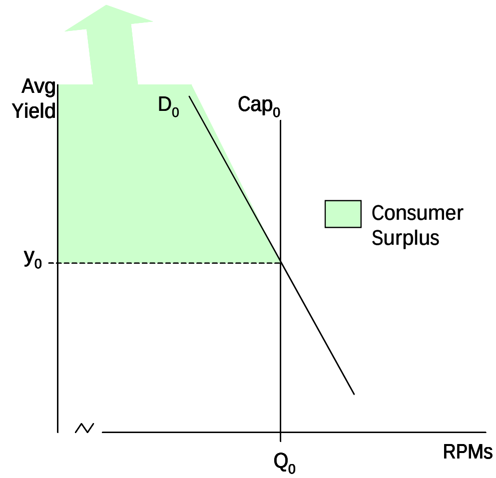
Figure 2-37 shows a graphical representation of consumer surplus as the area above the price level (y_0) and below (to the left of) the demand curve (D_0). Because it is uncertain where the demand curve intersects the vertical price axis, total consumer surplus is not usually estimated. However, it is often possible to estimate the change in consumer surplus that would result from an increase or decrease in the market clearing price. Change in consumer surplus provides a measure of the increase or decrease in benefits to purchasers if the price for the good or service becomes lower or higher.

Yield Management

Airlines, like other businesses, use their knowledge of markets and customers to craft products and prices that better match the needs and preferences of specific passenger and cargo market segments.

In commercial aviation, such price and product segmentation tools are termed "yield management." As a practical matter, yield management is extremely complex, and even for individual city pair markets, the fare levels at which tickets are actually sold can vary day by day, as can the number and size of the fare "buckets" into which passengers are segmented.

Figure 2-37. Initial Market Conditions for Airline Average Yield and RPMs (with Graphical Illustration of Consumer Surplus)



With daily changes in the number of seats sold for given fare levels (fare levels which may themselves vary), the "average yield" (average price per passenger mile flown) also changes on a daily basis.[82] Thus, like most actual markets, the market for passenger air transportation is complex and would be impractical to model (in terms of both data availability and feasibility) without important simplifying assumptions. Such simplifying assumptions make it possible to create models to forecast future demand for domestic air transport services and to quantitatively assess the impact of capacity shortfalls on the users of the air transportation system.

A key simplifying assumption for forecasting future demand concerns airline yield (revenue per passenger mile flown). Airline yield management programs are intended to match fares charged with the value of the service provided and thus vary yield depending on the passenger—e.g., differences between business and leisure traveler fares is a familiar example of airline yield management.

Due to differences in costs and demand, yields also vary depending on flight distance and departure and arrival airports. However, it is not feasible to estimate a model of airline demand that takes account the myriad sources of variability in yields. The SEDF study therefore employed a simpler model based on average annual yield (although many passengers will pay fares that imply yields higher and lower than this average value).

Related to the simplifying assumption that demand responds to average yields is the use of RPMs as the service that the average yield purchases. This, too, is a simplification of the fact that passengers buy tickets to fly specific itineraries, rather than to fly without regard to the place of departure or arrival. However, as with the myriad sources of variability in actual yields paid by passengers, at the national level it would be unfeasible to estimate a model of demand for numerous possible flight itineraries, rather than for RPMs in general.[83]

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[82] A recent valuable treatment of the economics of yield management in the airline industry is Michael E. Levine *Price Discrimination without Market Power.* Yale Journal of Regulation, Winter 2002.

[83] For modeling capacity constraints in the face of growing demand, it is necessary to allocate "generic" RPMs to specific routes and sectors of airspace, as discussed in chapter 3 of this report. However, the allocation of future traffic relies on the overall estimated demand for RPMs, which is developed through demand models discussed here.

Figure 2-37 depicts the starting point for the assessment of a shortfall between demand and capacity in the air transportation market. It shows system capacity-driven supply and demand for annual domestic RPMs and represents the initial point of the capacity analysis, which is set in 2005 and is described more fully in the discussions of demand forecasting and capacity modeling below. For the starting year 2005, the figure depicts current system capacity and RPMs demanded at a level denoted Cap_0 or Q_0. At the average yield y_0 the market for system-wide RPMs clears, reflecting the point at which the initial demand curve D_0 intersects the system capacity constraint Cap_0.

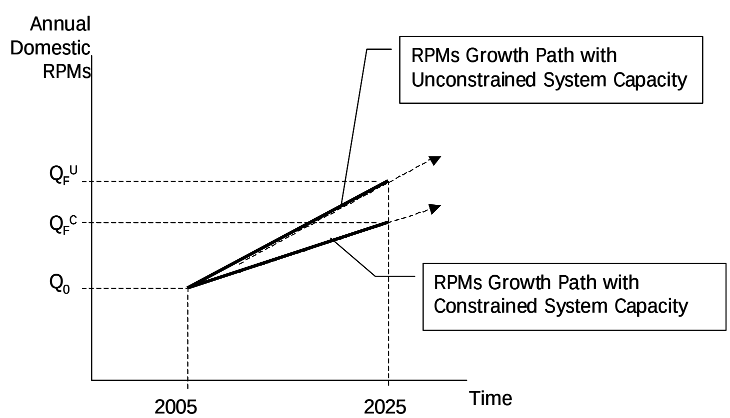
The figure also illustrates the concept of consumer surplus described above. Consumer surplus is represented by the shaded area bounded from below by the market-clearing average yield y_0 and bounded from above and on the right by the initial demand curve $D_{0.}$

Figure 2-37 shows a graphical depiction of the market for domestic RPMs in 2005, the base year used in the quantitative shortfall analysis presented in chapter 3 of this report. To estimate future levels of RPMs, it is necessary to develop forecasts of growth in future demand and of the average yields that will match demand with available supply.

Growth in demand (passenger willingness to purchase RPMs to and from desired locations at specific prices) largely reflects growth in the overall economy. The specific amount of annual RPMs traveled in a future year such as 2025 (all other factors held constant) depends, in turn, on the average yield charged by air carriers. This yield is inversely related to the availability of airway and airport capacity in the overall aviation system. When the system has more capacity, airlines are able to provide more RPMs at lower average yields, which reflects the effects of both increased competition in the system and greater airline productivity. In a system with less capacity, fewer RPMs will be flown, at higher average yields. This outcome can reflect both reduced production efficiency for carriers operating in a more congested system and the ability of some carriers to raise fares in a market more affected by scarcity. Estimated values for these contrasting situations are presented in chapter 3 of this report, along with specific assumptions underlying the calculations leading up to them.

Thus, starting from the 2005 equilibrium output of annual domestic RPMs ($\mathbf{Q_0}$ in Figure 2-37) and the average system yield of $\mathbf{y_0}$ in 2005, future activity may grow at a faster or slower pace, depending upon whether or not system capacity growth accompanies the normal growth in the overall economy, which fuels growing demand for air transport services. These alternative growth paths for annual domestic RPMs are depicted graphically in Figure 2-38. The volume of RPMs

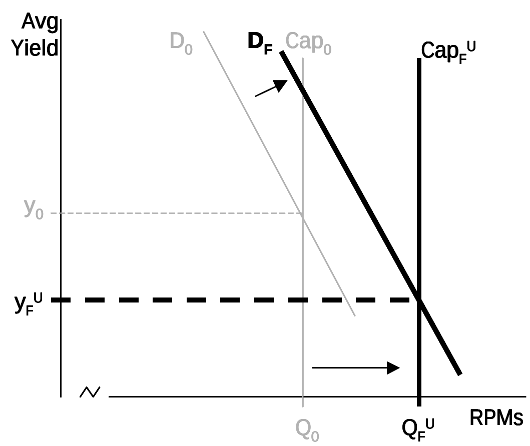
Figure 2-38. Growth in System-wide Domestic Annual RPMs for Unconstrained and Constrained NAS Capacity Environments



produced in the system in 2025—for both the constrained case (**Q_F^C**) and the unconstrained one (**Q_F^U**)—are modeled as the outcomes of a market clearing process similar to that depicted in Figure 2-37. These alternative market outcomes and a methodology for comparing them are described in Figures 2-39 through 2-41 and the accompanying discussion. Quantitative estimates for these values are presented in detail in chapter 3 of this report.

Two future air transportation environments are considered, each a development from the starting point depicted in Figure 2-37. The first depicts market-clearing in the unconstrained future environment, which would occur along the “RPMs Growth Path with Unconstrained System Capacity” of Figure 2-38. The first future environment is illustrated in Figure 2-39. This future setting for air transport activity is built from the assumption that sufficient new system capacity is added to accommodate anticipated growth in demand for RPMs. The anticipated future average yield and RPMs demanded are derived from the baseline demand forecast used in this study; this baseline forecast is discussed fully in chapter 3 of this report. Since this future for air transport is based on the assumption that adequate system capacity will be provided for accommodating demand growth from D_0 to the future level of demand D_F, it can be referred to as an “unconstrained” future environment.

Figure 2-39. Market Clearing Average Yield for Unconstrained Future Demand for RPMs (Based on Assumptions used for FAA Baseline Model)

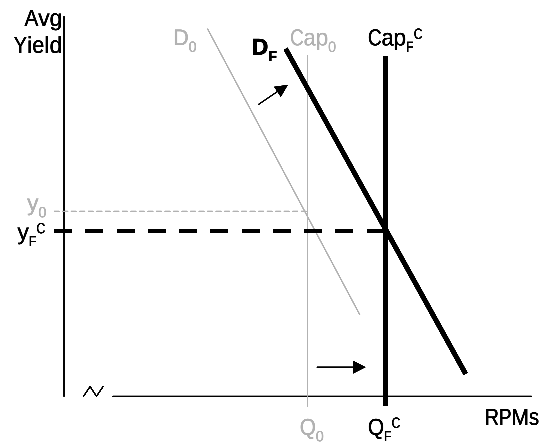


Thus, in Figure 2-39 the transition to an unconstrained future air transport environment is shown by the growth in demand from D_0 to its future level D_F, and by the increase in system capacity from Cap_0 to the future unconstrained capacity level of Cap_F^U. Airlines and other industry participants continue historical trends of steadily improving productivity, which allows unit production costs to continue their historical trend downward. These trends, which reflect the assumptions and data used in the FAA baseline forecast model used in the quantitative stages of this analysis, lead to a market clearing average yield of y_F^U, which is lower than the initial average yield of y_0.

Economic features of a second possible future air transport environment are illustrated in Figure 2-40. This figure depicts a future in which no additional system capacity-enhancing investments have been made beyond those called for in the OEP and planned future runway construction. In this future environment, system capacity also increases from the initial level depicted in Figure 2-37 because of system improvements already in the pipeline, but not by as much as the increase depicted in the unconstrained future environment of Figure 2-39. Because future capacity growth is limited to that already envisioned for the system, this future environment is referred to as a “constrained future”; it is the future growth path depicted in Figure 2-38 as the “RPMs Growth Path with Constrained System Capacity.” It is important to note that growth in future demand from D_0 to its future level D_F is driven entirely by growth in the economy, so the same curve for future demand for RPMs is depicted in both Figure 2-39 and Figure 2-40.

Figure 2-40. Market Clearing Average Yield for Constrained Future Capacity for RPMs

(Ordering of average yield magnitudes based on analysis of constrained capacity and operations in constrained future environment in chapter 3 of this report.)



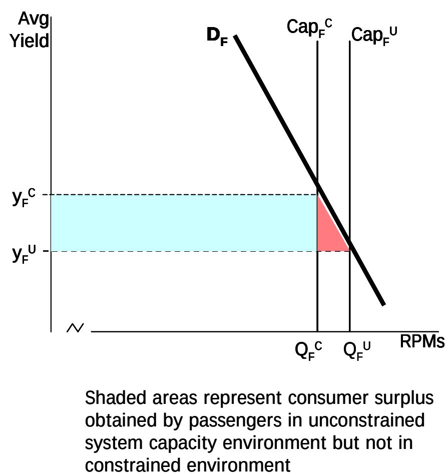
Thus, in Figure 2-40 the transition to a constrained future air transport environment is shown by the growth in demand from D_0 to its future level D_F (which as noted previously is independent of the absence or presence of new capacity), and by the increase in system capacity from Cap_0 to the future constrained capacity level of Cap_F^C. Airlines and other industry participants may be able to continue historical trends of steadily improving productivity, which allows unit production costs to continue their historical trend downward, relative to today's costs. However, the additional capacity constraints envisioned for this environment may lead to higher unit costs than occur in the unconstrained future environment. Nevertheless, there is a market clearing average yield of y_F^C, which is lower than the initial average yield level of y_0, although this average yield is higher than the unconstrained average yield of y_F^U.

Figures 2-39 and 2-40 graphically represent highly simplified snapshots of divergent future air transportation environments that could develop from the same starting point depicted in Figure 2-37 (along the growth paths depicted in Figure 2-38), depending on future choices about the provision of new NAS capacity beyond what is already planned. Whichever future environment emerges depends on choices and plans that would be made well before the time that the later figures represent, and the two environments would likely be significantly different. A quantitative comparison, however, requires simplification of the differences so that the two future environments can be set side by side for comparison. In this study, the value to consumers of investment in NAS capacity beyond that already planned is measured by the additional consumer surplus "gained" by passengers in a future environment with unconstrained NAS capacity compared to a constrained future resulting from a lack of such investments.

One of the assumptions that makes this comparison more tractable is that the demand curve for domestic RPMs is the same in the two future environments. This assumption, and the comparison of the market clearing average yields for the unconstrained system capacity case and the constrained case are depicted in Figure 2-41. In essence, this figure overlays the results for average yield and RPMs demanded for the two distinct environments of constrained and unconstrained system capacity. The value to consumers of attaining the unconstrained world (and the higher level of air travel it accommodates) rather than the constrained future can be estimated using the value implied by the shaded area. This area represents the effects of lower average fares paid in the unconstrained environment by passengers who would have chosen to fly in either future environment and the consumer surplus received by passengers who would have found average fares to be too high in the constrained world but would choose to fly at the lower average fares of the unconstrained future.[84]

Some or all of this difference in average yields may represent the effects of higher unit operating costs faced by airlines and other industry participants in the constrained future environment. To the extent that this is not the case, the higher average yields in the constrained future environment may include monopoly or scarcity rents—returns above the prevailing or market return to a factor—that airlines or their input suppliers are able to extract from passengers due to capacity constraints. If so, the presence of these scarcity returns represents a form of producer surplus that would not exist in the capacity unconstrained future environment. Instead, there would be greater consumer surplus in the capacity unconstrained world than would exist in the capacity constrained world.

Figure 2-41. Comparison of Consumer Surplus in the Unconstrained Capacity Future Environment and the Constrained Capacity Future Environment.



If the air transportation system is unable to meet future demand, embedded delays and other inefficiencies in the system are also likely to grow. Some travelers will encounter delays, some will encounter increased airfares, and some will be priced out of the market. All of these factors lead to losses in consumer surplus, as illustrated in Figure 2-42.

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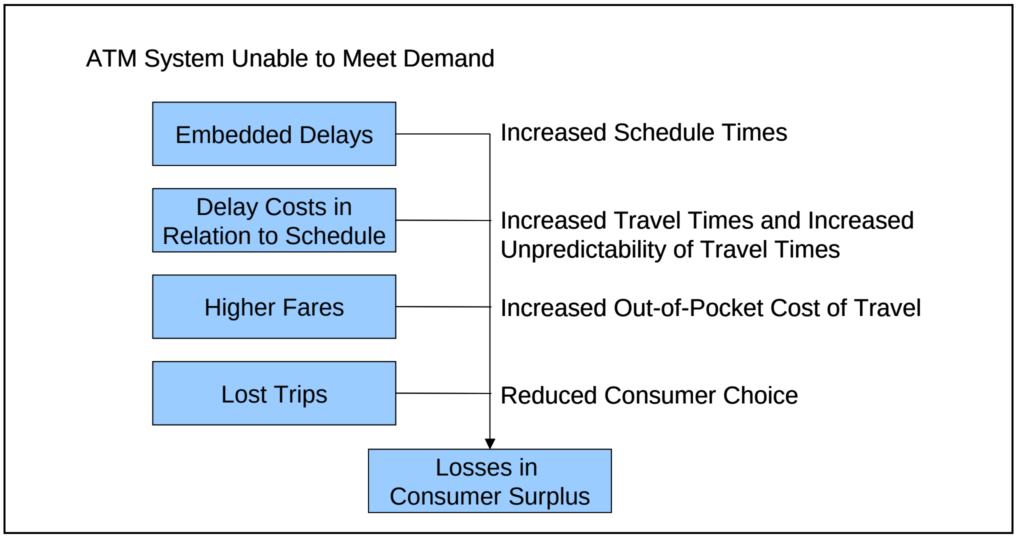
[84] While this figure (2-41) may resemble the type of graph often used by economists to depict analytical comparisons such as differences between monopoly and competitive markets, it is important to keep in mind that the comparison being made is between two distinct and abstracted future worlds which differ by the availability of air system capacity, and that it is not conceptually meaningful to imagine moving back and forth between them, as might be done when comparing a monopoly market to a competitive one.

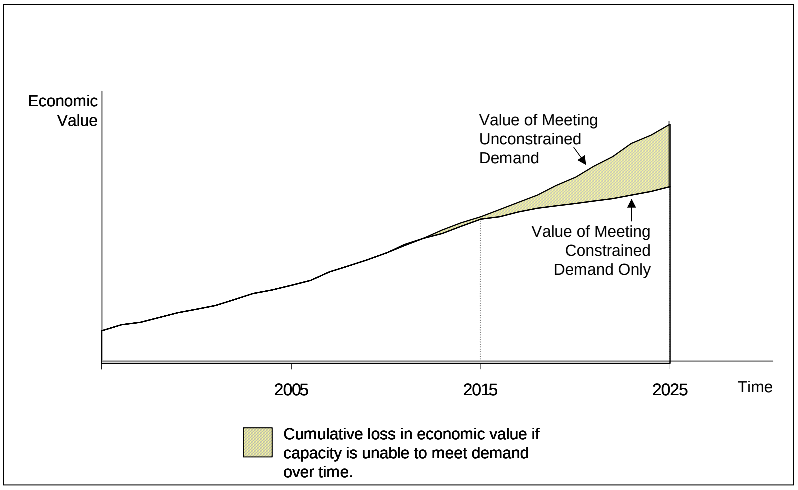
Figure 2-42. Economic Costs of the Shortfall



The transformation of the national air transportation system that could prevent these losses arising from a shortfall between NAS capacity and demand will not be without cost, of course. A complete cost benefit assessment of the transformation would compare the costs associated with specific plans and systems that would achieve this transformation with the value to the national economy of avoiding the losses arising from a capacity shortfall. Such detailed assessments will be possible when specific strategies and proposals for transformation are more closely considered.

While Figure 2-42 depicts various components of the economic cost of capacity shortfalls, Figure 2-43 depicts the growth in their total value as growing demand for air transportation, which keeps pace with a growing economy. The figure illustrates the continued growth in the annual economic cost of capacity shortfalls over time. For a given level of unconstrained demand that cannot be accommodated by a system that is static or growing more slowly than demand, there will be a gradually increasing loss to the economy that accompanies that capacity shortfall, as indicated by the shaded portion or "wedge" of Figure 2-43. [85]

Figure 2-43. Illustration of Growing Economic Costs of Capacity Shortfalls



[85] As noted previously, this does not speak to the costs necessary to remedy the capacity shortfall or how to pay for it.

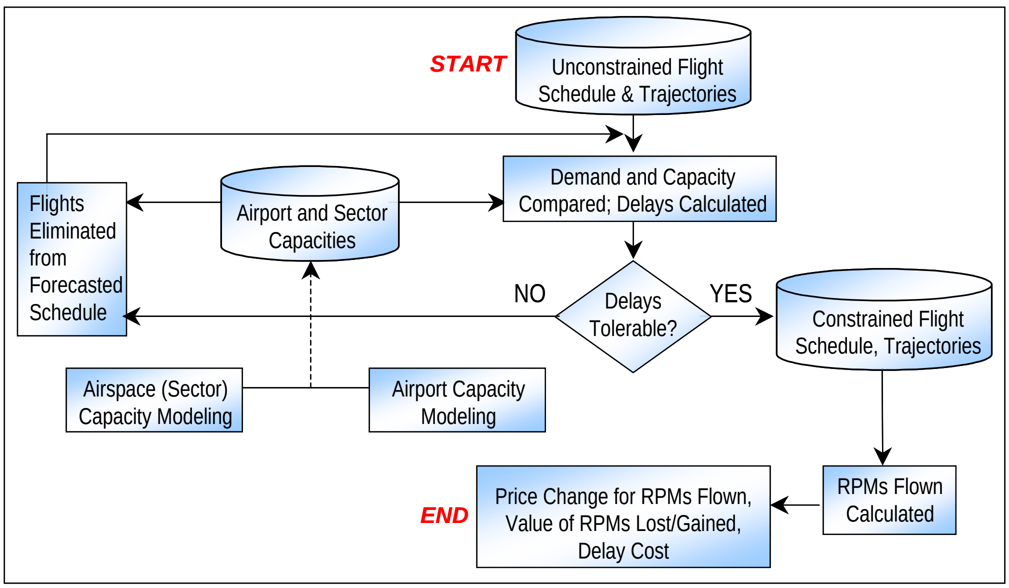
Chapter 3. Futures and Forecasts

This chapter discusses the modeling of the future NAS capacity and forecasting of the public's demand for air travel. The analysis shows that without further investment in infrastructure improvements, procedural and policy changes, and technology research and development, the NAS will be unable to deliver the quality and quantity of service expected by air passengers. We present this performance degradation in terms of the lost economic value to the nation due to the shortfall between capacity and demand.

METHODOLOGY OVERVIEW

The cornerstone of the SEDF study's analytic approach to estimating the future NAS demand/capacity shortfall involves comparing the forecasted demand for air travel with a forecast of feasible air travel service that explicitly accounts for the impact of airport and airspace capacity constraints on flight schedule planning. Figure 3-1 shows an overview of the process we follow.

Figure 3-1. NAS Demand/Capacity Shortfall Assessment Methodology



The SEDF methodology begins by forecasting a future flight schedule, for nominal day-to-day operations (year 2015 and year 2025), including each flight's origin and destination (O&D), departure and arrival times, and aircraft type. The flight schedule is generated incorporating both commercial (domestic and international) and GA air traffic. For each flight, we also generate a four-dimensional trajectory; i.e., the flight path. We describe this flight schedule as "unconstrained." The schedule embodies the demand at airports while the associated trajectories embody the demand on the airspace, without consideration of capacity limitations.

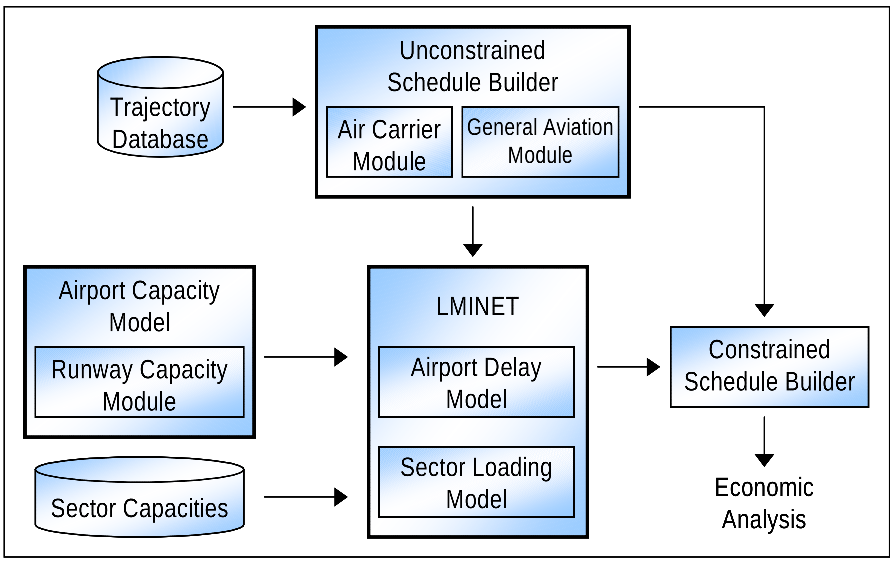
The process continues by comparing the demand to capacities of the airports and airspace. The airport capacities are calculated based on the number of runways and the configuration being used depending on the meteorological conditions. For the airspace, the en route sector capacities are specified as the maximum number of allowable aircraft within each sector per unit time. The predicted capacity/demand imbalance would result in unacceptable levels of chronic congestion and delays. Flights are eliminated until delays do not exceed tolerable limits to produce a tenable flight schedule, which we describe as "constrained" in which some demand remains unsatisfied due to the capacity constraints.

Calculating the number of flights that would be eliminated to produce the constrained schedule is fundamental to the shortfall assessment because it allows us to estimate the limits to growth in the NAS and the associated lost value to the nation. To perform the economic valuation, we convert the lost flights to lost RPMs for which we then estimate a value in terms of lost economic consumer surplus. The definition of consumer surplus[86] is "the maximum sum of money a consumer would be willing to pay to consume a given amount of a good, less the amount actually paid." In the context of the SEDF analysis, the change in consumer surplus represents the total lost value of the foregone demanded RPMs that cannot be delivered because of the capacity shortfall coupled with the resultant higher price of travel to the flying public (the fares paid for the delivered RPMs and the fares that would have been paid for the lost demanded RPMs).

MODEL DESCRIPTIONS

The SEDF analysis requires a modeling process that forecasts future demand, incorporates system capacity at the different NAS components (airports, en route sectors), estimates delays at each of those components, and represents aircraft flights and traffic flow with sufficient fidelity to estimate the system performance shortfall in 2015 and 2025. To execute this process, we use a suite of connected models as shown in Figure 3-2.

Figure 3-2. Model Interrelationships



We start by populating and using a database of flight trajectories to generate the traffic demands on the NAS. Feedback algorithms identify sectors and airports in which demand for air traffic control service exceeds capacity limits. Flights are then delayed in the future forecast schedule, or they are eliminated if delayed for an excessive period of time that would make such a scheduled flight untenable from an operator's perspective. The sector capacities are provided as input to LMINET; they are the maximum number of allowable aircraft within each sector per unit time. Airports are modeled through a queuing network. Airport capacity is estimated as a physics-based process based on aircraft performance, the quality and quantity of available information (e.g., aircraft position and speed), and controller objectives. The airport capacity models estimate maximum arrival-departure rates using user-defined parameters that reflect the impact of new technologies, procedures, traffic mix, airline schedules, and other factors. This section provides descriptions of the various models that we use.

[86] Consumer surplus is the economic measure recommended by the OMB for use in benefit-cost analyses of federal programs.

UNCONSTRAINED SCHEDULE BUILDER

The term "air traffic demand" is a loosely defined concept that can mean anything from aircraft operations, to passenger enplanements, to the number of RPMs at different aggregation levels. We are interested primarily in the *schedule* of aircraft flights because that is the variable that determines air traffic demand both at the airports and air traffic control sectors. Specifically, a schedule is a flight from the origin airport to the destination airport, leaving at a certain time and arriving at a certain time, operated by an air carrier using certain equipment with a certain passenger/load capability.

The unconstrained schedule forecast generation method uses different approaches for the air carrier traffic component and the GA traffic component as detailed in the following sub-sections.

Air Carrier Module

The SEDF approach for forecasting the unconstrained air carrier traffic demand [87] includes the following assumptions:

- The schedule provided by the air carriers is the variable of interest, which reveals everything about air carriers' operations.
- We seek to construct an industry-wide model instead of one that integrates carrier-specific models. The air transport industry in the United States is an oligopoly and it is impossible to predict the industry configuration or market share in the future. By taking the industry as a whole, while still assuming the existence of competition among the carriers, we avoid attempting to predict winners and losers in the competition.
- The FAA's Terminal Area Forecast (TAF) is used as an initial input; therefore, the future schedule we derive must meet the TAF forecast at the airport level. Because the air traffic demand forecast in TAF is essentially based on historical and economic data, the airport and air traffic control service capabilities are not considered as constraints to the traffic demand.
- The traffic growth rate between two cities must be proportional to the traffic growth rates in both cities, respectively, if the terminal growth rates in other cities are unchanged.
- Current air carriers' operational practices are rational and will be unchanged in the future. By "rational," we mean that the air carriers, being commercial companies, will try to maximize their profits by putting their resources or schedules where the demand is. The assumption of rationality of air carriers can be decomposed into the following:
    - The current (as of the day of actual traffic data used) Official Airlines' Guide (OAG) schedule is the best one to meet current air travel demand.
    - The air carriers will continue to conduct flight bank operations in hub airports. Since airline deregulation in 1978, the carriers have had the freedom to design their schedules as they see fit except for a few slot-controlled airports. Since then, air carriers have consolidated their operations to concentrate on a few hub airports, which are characterized by alternating banks of arrivals and departures. There are two major advantages of bank operations: first, the number of markets, through connection at the hub, is greatly expanded—offering travelers choices that cannot be made through point-to-point operations; second, the airline that has the dominant market share at the hub cities commands premium fares. While there may be some growth in "point-to-point" operations, we assume that the prevailing air carrier strategy will continue to be "hub-and-spoke."

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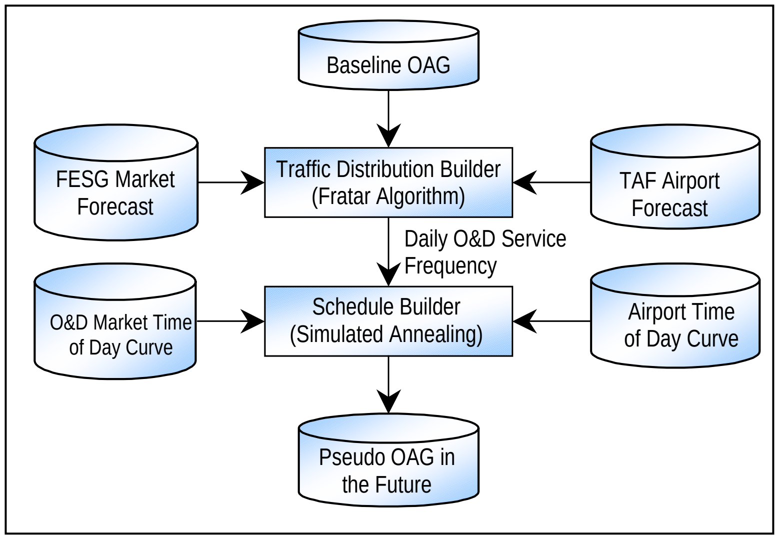
[87] NASA, A Method for Forecasting the Commercial Air Traffic Schedule in the Future, NASA Contractor Report 208987, Dou Long, et al., 1998.

- The time-of-day demand pattern will not change. Given the total number of people willing to travel from A to B in a day, research by airlines and Boeing shows that the distribution of that demand across the day depends on the local departure and arrival times and the journey time, where business travelers and leisure travelers may have different demand patterns, and, of course, different demand elasticities.

Figure 3-3 shows the process for generating the future unconstrained commercial flight schedule and reflects the assumptions above.

Figure 3-3. Unconstrained Air Carrier Flight Schedule Generation



We start with a baseline schedule, specifically an OAG schedule from a day in 2000, and a national air travel demand forecast, specifically the latest version of the TAF, [88] and the latest version of the Forecasting and Economic Support Group (FESG) Market Forecast[89]. These inputs feed the Traffic Distribution Builder model. The FESG provides a forecast at the regional O&D level, by equipment category, while the TAF provides a forecast at the airport level. If these forecasts are wrong and the demand growth is either higher or lower, then the benefits we calculate would be affected. The Traffic Distribution Builder first uses the FESG forecast to "stretch" the current traffic to the future forecasted level. Then, for the airports included in the TAF, the Fratar algorithm, a widely used method for generating trip distributions, is used to satisfy the terminal forecast. At this point in the process, we can predict the total daily O&D flights for all airports in the world. This includes all forecasted flights between the LMINET network airports, domestic flights to/from non-network airports, and international flights to/from the network airports.

Given the total daily O&D flights, we must now incorporate time-of-day patterns to assign the flights to particular departure times. There are actually two kinds of time-of-day demand curves/functions. One is the demand as a function of the local time at the airport. This reflects the fundamental passenger time-of-day preference as well as airlines' hub operation practice. In general, there is a pattern of alternating peaks of departures and arrivals interleaved together, which mostly reveals the hub operation. Another kind of time-of-day demand function is defined at the O&D market level. The service in the market is roughly uniformly distributed from the beginning through the end of the day; however, this must be adjusted, for example, to account for long transcontinental flights from the west coast to the east coast. Flights departing in the afternoon local time would result in arrivals after midnight on the east coast and thus few such flights are scheduled. To accommodate these patterns, the first step in the Schedule Builder model is to, for each O&D pair,

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[88] FAA, FAA Aerospace Forecast, Fiscal Years 2003-2013, March 18, 2003.

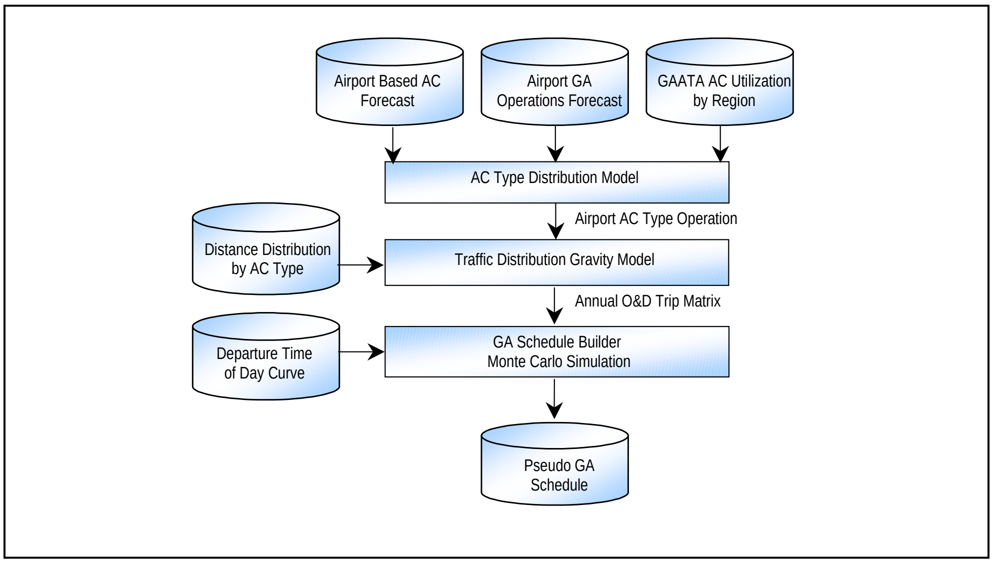
[89] FESG, *Report of the Forecasting and Economic Support Group (FESG) to CAEP/4.* International Civil Aviation Organization Committee on Aviation Environmental Protection, Montreal, Canada, April 1998.

generate half of the added flights according to the departure time-of-day patterns at the departure airport, and generate the other half of the added flights according to the arrival time-of-day pattern at the arrival airports. The schedule is considered "constructed" once the profiles based on the flight schedule and the pre-selected ones are minimized. Since it is a complicated optimization problem involving tens of thousand of flights and the evaluation of hundreds of objective functions, we need to find a solution that can overcome the local minima and reach to the global minima—thus the final step is to adjust the flight schedules based on the simulated annealing technique[90] which reaches such a desired solution.

General Aviation Module

While the commercial air transportation market largely operates on published flight schedules, GA is characterized by itinerant and local operations for which there is no analogue to the commercial OAG. Thus generating a future unconstrained GA air traffic schedule forecast[91] requires a significantly different process than that for commercial air traffic. And though we talk of generating a "GA schedule," this does not mean that the future GA operations will be scheduled; rather, it is simply an expression of the forecasted GA flights in terms of O&D as well as time. The process is illustrated in Figure 3-4.

Figure 3-4. Process for Generating Future Unconstrained GA Air Traffic Schedule Forecast



In the GA schedule forecast module, the based aircraft forecast, and the GA itinerant forecast for each airport come from the output of the top-down model of the Integrated Air Transportation System Evaluation Tool (IATSET)[92]. The tool allows us to forecast the future distribution of GA aircraft and GA itinerant operations, the size of the GA fleet, fleet productivity, and transported passenger miles (TPMs).[93]

To estimate growth in GA passenger miles transported under the baseline scenario, we use the following techniques and assumptions. Baseline GA transport passenger miles for the year 2000 are estimated using the FAA GA survey values for flight hours for corporate, business, personal and air

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[90] Logistics Management Institute, Upgrading LMINET— A Queuing Network Model of the National Airspace System, Dou Long, et al., February, 2002.

[91] Dou Long, David Lee, Jesse Johnson, and Peter Kostiuk, *A Small Aircraft Transportation System (SATS) Demand Model*, NASA/CR-2001-210874, June 2001.

[92] Earl R. Wingrove III, Jing Hees, and James A. Villani, *The Integrated Air Transportation System Evaluation Tool*, NASA/CR-2002-211961, November 2002.

[93] A transported passenger mile is one passenger transported one statute mile in a GA aircraft. The concept is analogous to the revenue passenger mile used for measuring the output of U.S. commercial air carriers.

taxi users by aircraft type; i.e., single-engine non-jet, multi-engine non-jet, and jet engine GA aircraft. From these hours flown, the available GA passenger seat-miles are estimated using averages for the seats per aircraft type and aircraft speed and assuming a 65% load factor for GA passenger transport operations.

From this baseline, we estimate future levels of GA transport passenger miles using the following methodology. First, we recognize that there are different growth rates for different aircraft types. The current GA share of total domestic passenger miles of 2.6% is used as a central tendency for future GA shares of overall domestic RPMs. From this central tendency of 2.6% growth, a poor environment for GA—which may be due to few limits to system growth and/or unattractive substitutes to scheduled service models—will reduce future GA share and a good environment will increase future GA share. For the least aggressive GA growth scenario, the current split of GA transport miles among the various vehicle types is used as the split that will exist in 2025. In more aggressive GA growth scenarios, the faster growth in GA transport passenger miles is assumed to be more concentrated in jet engine aircraft. The baseline shares in future years are the approximate mid-points between the upper and lower forecasts. With these estimates of future levels of GA activity by vehicle type, it is possible to impute levels of GA TPMs.

We then use the IATSET to convert aggregate-level forecasts of TPMs for the baseline scenario into a detailed forecast of activity at the airport-level. Having estimated the level and distribution of TPMs by aircraft type, we estimate measures of GA activity (the number of operations). Then, we distribute the different types of aircraft and the GA itinerant operations among 2,865 airports according to the IATSET model.. The General Aviation and Air Taxi Activity database contains detailed information about GA and air taxi itinerant operations at the regional level. From these data, the Aircraft Type Distribution Model decomposes the itinerant traffic by aircraft type at each airport.

An analysis of data from the Enhanced Traffic Management System (ETMS) allows us to construct a probability distribution function for the distances flown by the various aircraft types (single engine, multi-engine, and jet equipment). This is used by the Traffic Distribution Gravity Model to get the annual O&D distribution. The gravity model has been used widely in O&D demand modeling studies in which researchers have used population, per capita income, and other criteria as masses and pecuniary expense or time of travel as cost. Such models are called “gravity model” because they mimic the form of Newton’s Gravity Law. In the simplest form, such models are expressed as:

$$t_{ij} = m_i^{\alpha_i} \cdot m_j^{\alpha_j} \cdot c_{ij}^{\beta}$$

where i,j = 1, 2, 3,…, N.

The term t_{ij} is the traffic from city *i* to city *j*; m_i and m_j are the “masses” of city *i* and *j*, respectively; and c_{ij} is the “cost” or the “attractiveness” of traveling from city *i* to city *j*. The terms α_i, α_j, and β are the model parameters to be estimated.

We then create a detailed schedule for the O&D distribution that has been constructed and the schedule must take into account the time of day departure profile We estimate the profile by using the GA flight counts recorded in the ETMS data. We assume most GA aircraft can travel just a few hours before refueling. Because the GA schedule is based on these time profiles, and there are few O&D flights between airports, some of the forecasted demand is calculated to be a fraction of a flight. The Monte Carlo simulation technique overcomes this deficiency by generating integer numbers of flights in the GA schedule based on the probabilities specified by the time-of-day departure profile and O&D distribution model.

Treatment of Air Cargo Operations

The air transportation industry serves diverse needs both for passengers and for shippers. Because users of air cargo are disaggregated by industry and commodity, sometimes at great detail, it may appear that these users of air transport are more diverse than passenger users, who are usually separated only as business travelers or leisure travelers. However, it is also true, even though data are not collected at this level, that individual business travelers are engaged in specific industries, just as commodities are shipped to and from specific industries.

Cargo operations and passenger operations are dissimilar in other ways. Congestion, delays, and other system shortcomings resulting from capacity constraints are caused in part by the natural human preference for travel at particular times of the day, especially during early and late daylight hours. Innovations and improvements to the NAS allow larger numbers of passengers to continue to travel at these preferred times. Cargo, on the other hand, is moved primarily during nighttime hours, when the effects of congestion are much less pronounced. For many products shipped by air, it is possible to substitute other modes of transport for some or all of the air portion of the shipping process. Such substitutability across modes is much less possible for passenger air travel, especially business travel.

For these reasons, freight users of air transport are less severely affected by system congestion and capacity strains than are passenger users. The portion of cargo carried as belly cargo on passenger operations is an exception, and shortfalls in service quality for belly cargo users may result in a larger all-cargo fleet. Belly cargo is often treated and priced as a byproduct because it is secondary to the purpose of airline operations, which is transporting passengers. As such, the scheduling and routing of passenger aircraft are based on passenger demand and not on cargo demand. (This is reflected in the often low load factors achieved in belly cargo utilization by passenger airlines.) Accordingly, this initial socio-economic demand forecast and analysis of the interactions between future demand and future NAS capacity is focused on the capacity shortfall experienced by passengers and passenger operations. In the future, we intend to conduct a more detailed assessment of the relationship between air freight services and NAS capacity.

TRAJECTORY DATABASE

To estimate the airspace demand, we populate and use a trajectory database for both commercial and GA flights by their origin, destination, and equipment type. Then we use the database to assign a trajectory for every flight in the schedules. The trajectory database contains the following information recorded by the ETMS:

- Departure airport and arrival airport information such as airport location ID, latitude, and longitude
- Departure and arrival time
- Equipment type, which is coded in such a way that this data field also indicates whether the trajectory is for a commercial or GA flight
- All airspace sectors a flight flew through in time sequence with entry and exit time for each sector
- Total number of sectors each trajectory traversed
- Time a flight entered the first sector and time it exited from the last sector

We select one trajectory for each unique origin-destination (OD) pair and equipment type combinations. For those OD pairs with more than one trajectory, we use a selection criterion that is based upon average flight time. The trajectory selection process includes the following steps:

1. Rank all trajectories by total flying time in each OD pair and equipment type combined group

2. Index those trajectories as 1, 2, 3, …, in each group

3. To pick one trajectory in the group: Pick index = INT((1+count)/2); where INT means integer, and count is number of trajectories in that group.

In this method, we use the median flying time as a proxy of the average flying time to avoid possible no-exact-match situations.

To derive the daily profile of airspace demand for a future flight schedule, we merge the selected trajectories with the future commercial and GA flight operations by origin, destination, and equipment type. Then, we adjust each airspace sector's entry and exit time in a trajectory according to a flight's scheduled departure and arrival time. With the information on flights' location at a given time, we are able to obtain airspace demand in each of airspace sectors at a given time of the day.

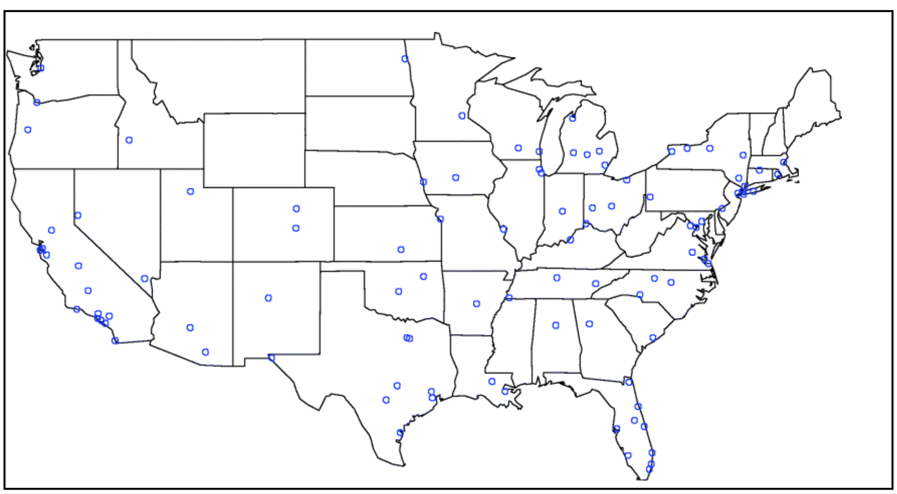
LMINET

In general terms, LMINET models flights among a set of airports by linking queuing network models of the airports with a sector loading model of en route, Terminal Radar Approach Control (TRACON), and Air Route Traffic Control Center (ARTCC) sectors. We specify the sequences of sectors to represent various operating modes for the NAS. In this study, the sequences correspond to trajectories of flights as flown on a specific day as determined from ETMS data.

LMINET Airport Delay Model

The LMINET is a NAS-wide model which includes 102 airports[94], which are shown in Figure 3-5.

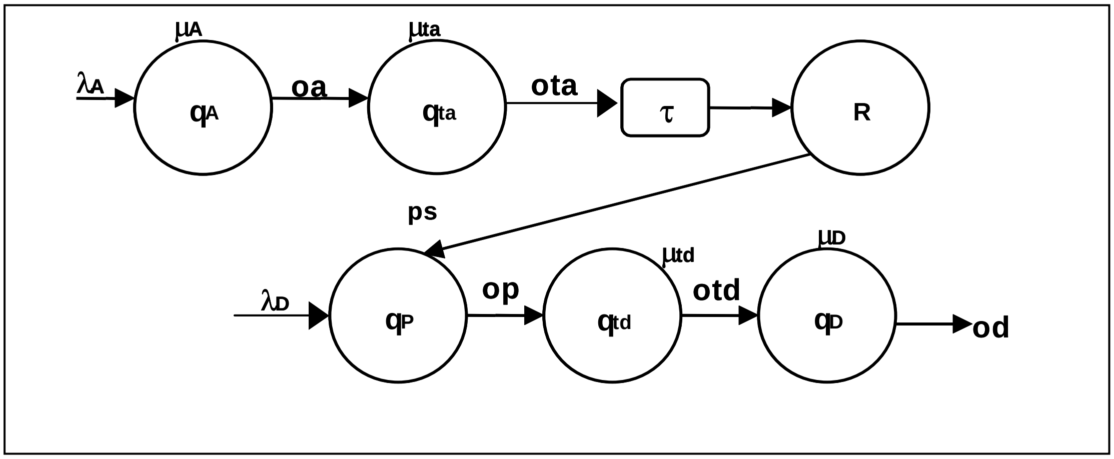
Figure 3-5. 102 LMINET Airports



Operations at each of the airports are modeled by a queuing network, as shown in Figure 3-6.

[94] The 102 airports (denoted by three-letter codes) are ABQ, ALB, ANC, ATL, AUS, BDL, BFL, BHM, BNA, BOI, BOS, BTR, BUF, BUR, BWI, CHS, CLE, CLT, CMH, COS, CRP, CVG, DAB, DAL, DAY, DCA, DEN, DFW, DSM, DTW, ELP, EUG, EWR, FAT, FLL, FNT, GFK, GRR, GSO, HNL, HOU, HPN, IAD, IAH, ICT, IND, ISP, JAX, JFK, JNU, LAN, LAS, LAX, LGA, LGB, LIT, MCI, MCO, MDW, MEM, MIA, MKE, MLB, MSN, MSP, MSY, OAK, OKC, OMA, ONT, ORD, ORF, PBI, PDX, PHF, PHL, PHX, PIT, PVD, RDU, RIC, RNO, ROC, RSW, SAN, SAT, SBA, SDF, SEA, SFO, SJC, SLC, SMF, SNA, STL, SWF, SYR, TPA, TUL, TUS, TVC, and TYS.

Figure 3-6. Queues in the LMINET Airport Model



Traffic enters the arrival queue, q_A, according to a Poisson arrival process with parameter $\lambda_A(t)$. Upon service by the arrival server, an arriving aircraft enters the taxi-in queue, q_{ta}. After the turnaround delay, τ, the output of the taxi-in queue enters the ready-to-depart reservoir, *R*. Each day's operations begin with a certain number of aircraft in this reservoir.

Departures enter the queue for aircraft, q_p, according to a Poisson process with rate λ_D. Departure aircraft are assigned by a process with service rate $\mu_p(t)$. When a departure aircraft is assigned, *R* is reduced by 1. Having secured a ready-to-depart aircraft, the departure leaves q_p and enters the queue for taxi-out service, q_{td}. Output from the taxi-out queue is input to the queue for service at a departure runway, q_D, where it is served according to the departure service process with rate μ_D. Finally, output from the departure queue, $q_{D,}$ is output from the airport into the rest of LMINET.

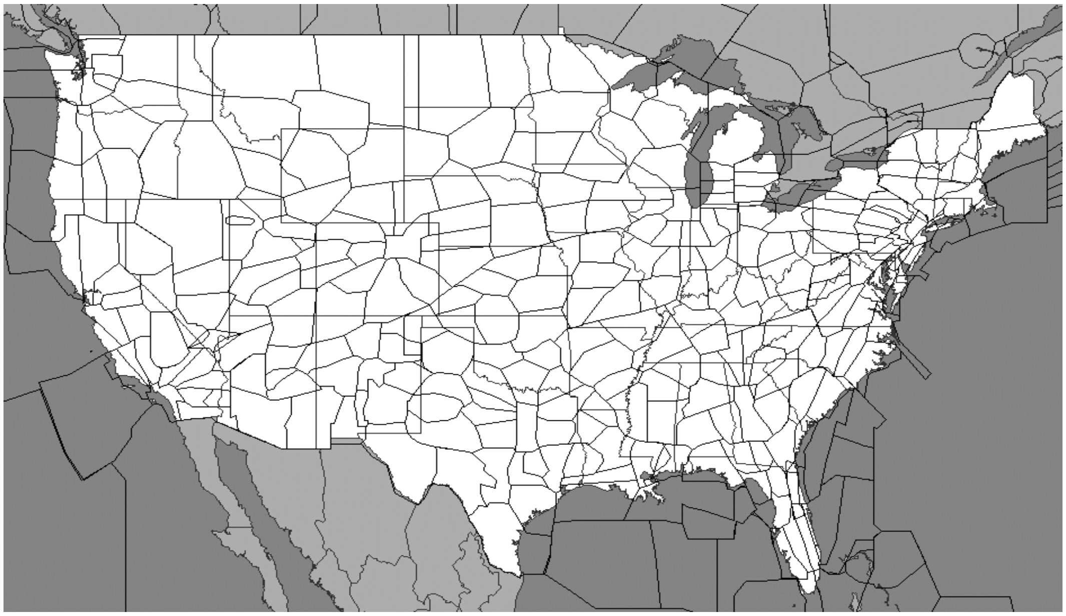
LMINET Sector Loading Model

The LMINET sector model follows the airspace operation procedures as in the current NAS, albeit with projected air traffic control capacities and flights. In general, a flight trajectory is a 4-D curve that shows an aircraft's position during a flight for every time since its departure. The flight trajectories of the future scheduled flights are taken as flown in the current NAS matched by the origin, destination, equipment type, and the time and trajectory flown.

We use the air traffic control sector definition used by FAA in December 2000. Sector boundaries are determined by observing traffic and controller workload patterns. Sector airspace is built around traffic flows and approach corridors, and it is designed to equally distribute traffic load and minimize converging traffic, transitioning traffic, and coordination with other facilities. A sector can be classified as "low," "high," or "super high." In low sectors traffic travels at an altitude that is less than or equal to 23,000 feet. Most approach control facilities or TRACON facilities control traffic in this type of sector because most traffic is entering or departing a terminal airport. Traffic in high sectors flies at an altitude between 24,000 feet and 33,000 feet. High sectors are designed around the traffic flow along major jet routes, known as "highways in the sky." Some centers have super high sectors with altitudes 33,000 feet and above; other centers have super high sectors that begin at 35,000 feet. Figure 3-7 shows the high sector boundaries in the United States.

In this study, consistent with the FAA's practice, we define sector flight demand as the maximum number of flights simultaneously in the sector in every 15-minute interval. If the sector demand exceeds its Monitor Alert Parameter (MAP), then some action will be taken (e.g., delaying the departure time, rerouting) to some flights to make the demand below the MAP. MAP is thus the sector capacity, which is determined by the volume and complexity of the traffic, the sector definition, and the radar coverage. MAP is typically 18 for most of the enroute sectors in the current system.

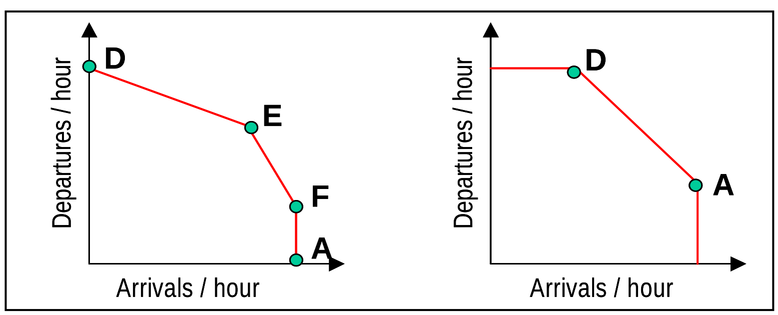
Figure 3-7. Sector Boundaries in the United States



AIRPORT CAPACITY MODELS

We use individual capacity models for the 102 airports to determine service rates to the arrival and departure runways. These models generate arrival and departure capacities as functions of surface meteorological conditions (ceiling, visibility, wind speed and direction, and temperature) and arrival and departure demand. The runway configuration used at the airport is chosen based on the above factors. We define runway capacity as a Pareto frontier, such as shown in Figure 3-8.

Figure 3-8. Sample Pareto Frontiers of Maximum Runway Capacity



All cases of arrival rate/departure rate inside the region bounded by the capacity curve and the axes are feasible. The capacity curve itself is the set of feasible points at which not both arrival rate and departure rate can be increased. Point D represents the runway being used for maximum departures, point A is for maximum arrivals, point E is balanced arrivals and departures, and point F is maximum arrivals with some “free” departure slots available. Free departures are those that can be accommodated even when the airport is configured for maximum arrivals. The Pareto frontier shown on the right side of Figure 3-8 represents a less detailed depiction of runway capacity.

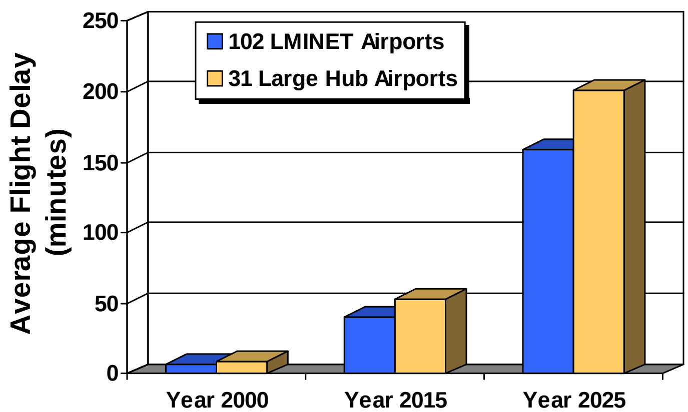
We develop capacity from a “controller-based view” of runway operations. That is, we assume that a human controller manipulates aircraft, introducing time (or, equivalently, space) increments in traffic streams to meet all applicable rules—e.g., miles-in-trail requirements, single-occupant rule—with specified levels of confidence. The desired confidence may differ from rule to rule. For example, while respecting all rules, controllers may want greater confidence that two aircraft never attempt to occupy a runway simultaneously than that miles-in-trail minima are met.

CONSTRAINED SCHEDULE BUILDER

Future demand forecasts such as the FAA TAF represent unconstrained demand; i.e., there is no accounting or adjusting for airport and airspace capacity limitations. Using the LMINET delay model, for this study we have first exercised the analysis without the feedback loops in order to illustrate the magnitude of the future capacity-demand imbalance and to provide motivation for the concept of creating a "constrained" schedule. Figure 3-9 shows an estimate of average delay per flight under good weather conditions for all 102 LMINET airports and for a subset of the 31 large hub airports[95] included in the 2001 FAA benchmark capacities study[96]. This subset includes the most congested airports in the NAS, and therefore their delays are indicative of the most binding capacity constraints on the system.

By 2025, the delays are projected to rise to 200 minutes at the large hub airports, if airlines and other air transportation community authorities were to do nothing.[97] But such a "do nothing" scenario is certainly invalid. Airlines cannot operate with such increases in average flight times, even when predictable, and the lost capital and labor utilization would make continued industry growth uneconomical. Instead of passively allowing such a situation of intolerable delays, we believe the forced industry response would be to leave a portion of the demand for air travel unsatisfied by scaling back the number of flights scheduled and flown.

Figure 3-9. Average Delay per Flight with Unconstrained Demand



The SEDF thesis rests on the idea that it is unrealistic to generate a future schedule in which the level of demand creates delays—under optimal weather conditions—greater than those that were experienced in the year 2000 at the busiest airports. The assumption is that those airports were then operating at close to their capacities. To generate a more realistic (i.e., "constrained") forecast, we impose a maximum delay per flight at each airport. Once the delay per 15 minute epoch reaches that maximum, no increase in flights is allowed during that period. In other words, when the departure and arrival queues become too large, the number of flights forecast for the future schedule must be reduced. The delay tolerance, at each airport, is the greater of either the peak quarter-hourly delay experienced at that airport, during good weather conditions in 2000, or the same figure averaged for the 31 large hub airports. By using this scheme, we allow the delay levels of today's less congested airports to grow as they experience more demand but still impose a reasonable overall constraint on airport delay. We use the peak delays (due strictly to demand, not weather), from 2000 because that year was characterized by very high levels of delay. The SEDF study team's interpretation is that while the NAS was experiencing high demand and was close to its capacity limits, the level of delay

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[95] If an airport has more than 1% of total domestic enplanements, it is categorized as a "large hub." The current 31 large hub airports are ATL, BOS, BWI, CLT, CVG, DCA, DEN, DFW, DTW, EWR, HNL, IAD, IAH, JFK, LAS, LAX, LGA, MCO, MEM, MIA, MSP, ORD, PHL, PHX, PIT, SAN, SEA, SFO, SLC, STL, and TPA.

[96] FAA, *Airport Capacity Benchmark Report 2001*, April 2001, available at http://www.faa.gov/events/benchmarks/

[97] These delay statistics were generated assuming that the only NAS improvement would be that additional runways identified in the FAA OEP would in fact be built.

was still tolerable, at least from the airlines' perspective. Thus, using these airport-specific delay tolerances, the model generates the excess arrivals and departures which must be eliminated.

Several policies could result in such an outcome: self-imposed airline restrictions and airport demand management rules, for example. The objective in enforcing this delay tolerance is to apply plausible limits on the growth in delay or block times, and thereby estimate limits to growth in the NAS. Calculating the number of flights that would be eliminated from the schedule is fundamental to the shortfall assessment. This allows us to estimate the limits to growth in the NAS in terms of fewer RPMs that would be flown. By valuing the lost RPMs we then calculate the economic loss.

Eliminating Flights to Produce the Constrained Schedule

There is the important problem of selecting which flights to eliminate from the future schedule; merely identifying a number of flights to eliminate is insufficient. Additionally, identifying flights to constrain based on a set of criteria allows flights of greater "value" to remain.

In formulating the problem, we take the premise that it is an industry-wide model in that 1) any flights operated in one particular O&D market will have the same value regardless of the operator; and 2) the network effect of the traffic is not considered explicitly. The first assumption simply states that the traffic demand will be provided by one operator or another to satisfy the demand, although we recognize that the one that actually provides the service probably will get the best benefit (profit) since it may offer the lowest cost or have the best network structure at the market. The second assumption enables us to avoid speculation about the industry configuration in the future and makes the construction of traffic at the higher level feasible. In many cases, the network effect may not be explicitly assumed if the algorithm removes both the long haul and short haul flights at the same time.

Let $f_1, f_2, \ldots, f_N$ be the unconstrained flights, and x_j be binary variable $\{0, 1\}$, where $x_j = 0$ indicates flight f_j is kept from the unconstrained schedule, and $x_j = 1$ if it is removed. If we follow the aforementioned assumptions and the assumption that any removed flight from the unconstrained schedule will not be substituted by other flights in other times or other O&D pairs, then finding the constrained traffic schedule can be formulated as the following 0-1 integer programming problem:

$$\min : z = \sum_{j=1}^{N} c_j x_j, \qquad \text{subject to:} \qquad \sum_{j=1}^{N} a_{ij} x_j \ge b_i, b_i \ge 0, i = 1, \ldots, M.$$

In the above formulation, $c_j \ge 0, j=1, \ldots, N$ is the traffic measure such as ASM, RPM, operations, etc. that we want to optimize. b_i is the traffic exceeding the capacity at service station i, which is a NAS resource (i.e., sector or airport) at a specified time. Since we use every 15 minute epoch (i.e., 96 per day) to calculate both arrival and departure demands at 102 airports with 995 air traffic control sectors, we have that $M = 115{,}104$. a_{ij} is a constant dependent on the flight schedule and trajectory: $a_{ij} = 1$, if flight j shows up at service station i, 0 otherwise. When finding the solution of the constrained schedule for a sample day, there will be about 100,000 flights, which is a daunting task with more than one million constraints. Commercial integer programming solver packages would have difficulty with a problem of this size. Instead, we need to find a heuristic for the solution.

We think the variable elimination heuristic is a natural choice for the solution strategy. First, if a flight does not go through any service station that is capacity constrained, then this flight must not be removed. Second, if we assume that in the optimal solution that $x_j = 1$, then the original optimization problem can be restated for the rest of the flights and with the capacity constraints modified. For those service stations with capacity violations that removed flight j traversed, their modified required eliminations will be adjusted downward by 1. When a flight is being removed from the schedule, it increases the objective function (a negative effect) and decrements the number of capacity violations to be resolved (a positive effect). Thus, the most likely flight to be included in the set of removed flights must be the one that gives the smallest contribution to the objective function while at the same time gives the biggest contribution to the capacity violations reduction. Once the most likely removed flight is identified, we can use the same method to identify the second most likely removed flight. This process goes on until there is no further capacity violations at any service station. The combinatorial optimization problem has thus been transformed to a sequential optimization problem. Formally, the heuristic is as follows:

Step 0 Compute the removal score for each flight j, defined as the sum of all the capacity violations b_i that the flight contributes to divided by the traffic measure c_j of the flight.

Step 1 From the set of eligible flights with positive removal score that has not been removed, find the flight j_{max} with the maximum score.

Step 2 If the finding of Step 1 is empty, then stop; otherwise:

remove flight j_{max},

update the capacity violations b_i*'s* that j_{max} has impacted,

update the removal score for all eligible flights,

go back to Step 1.

Although we have not used any linear programming or integer programming package to test the optimality of the variable elimination heuristic, we are convinced that it must a very good one. The variables being eliminated at the beginning stages, due to their high scores, are most likely in the optimal solution set. As the elimination process goes on, the reformulated problem increasingly becomes one with isolated constraints—the variables of non-zero coefficient do not appear across the constraints. For this kind of sub-optimization problem, it is straightforward to prove that the heuristic is optimal. In other words, we are quite certain that the flights removed at the beginning and ending stages of the process are the ones that should be removed by the optimal solution. Taking into consideration that the formulation is at the industry level, the solution provided by the heuristic is sufficient.

Measure of Optimization

We choose to optimize the number of operations. This is a conservative decision because it assumes that the NAS will continue to be operated as it is today; i.e., “equal opportunity, first come first served.” In other words, all flights are treated equally. It does not matter how many passengers are carried, whether commercial or GA; what matters is the NAS resources used (long flights traversing many congested sectors are penalized as are flights departing and/or arriving from/to congested airports). For a set of flights with the same flight elimination score, we choose to eliminate the one with the fewest RPMs.

Flight RPM Calculation

Since the flights are cancelled one by one, we need to compute the RPM for each flight, which is given by:

$$\text{RPM} = \text{statute\_mile} \times \text{number\_of\_seat} \times \text{load\_factor}.$$

The statute mile is straightforward. For the commercial flights, the number of seats of all flights in the same O&D pair is assumed to be their average in the baseline year adjusted by the system-wide averages in the future years (2015 and 2025). Average seats per aircraft and load factors are taken from the FAA forecast. For each year in the future, different figures are used for domestic and international flights. Figure 3-10 lists the parameters we used. Seats per domestic aircraft are assumed to rise moderately, from nearly 130 in 2000 to almost 135 per aircraft in 2025. Seats per aircraft used in international operations remains relatively constant over these years, in the 229 to 231 seat range. Domestic load factors are assumed to rise somewhat while international load factors are also relatively constant.

Figure 3-10. Average Seats per Aircraft and Load Factors				
Year	Seats per Aircraft, Domestic	Seats per Aircraft, International	Load Factor, Domestic	Load Factor, International
2000	129.6	230.6	70.5%	76.0%
2015	128.5	229.4	74.5%	76.6%
2025	134.6	231.7	75.0%	76.5%

For the GA flights, we assumed seat sizes of 8, 6, and 4 for the jet, multi, and single-engine aircraft respectively. We also assumed they have 65% load factor. These seemingly gross assumptions about GA, compared with those for the commercial flights, do not alter the constrained schedule much because their distances are mostly short, especially for the single and multi-engine aircraft, resulting in very few RPMs. In other words, the GA flights will be first to be eliminated no matter what the seat size and the load factor are, if other factors are equal.

AIR TRAVEL DEMAND FORECASTS

Demand for commercial air transport is considered a "derived demand"—i.e., the demand for air travel is the consequence of satisfying some other compelling interest, such as engaging in business or leisure activities. Unlike demand for many other goods, transportation services are not directly linked to demand for some final product. Therefore, forecasting demand for commercial air transport requires consideration of the variables that determine or "drive" that demand. These include various socio-economic determinants, such as economic, income, and population growth, as well as service determinants, such as airfares, seat availability, flight frequency, and the availability of substitutes.

Numerous academic, institutional, and industry models of demand for air transport (air transport of passengers and cargo) have been reviewed in order to determine what variables best explain air transport demand and how these variables can be used in forecasting demand. While industry research has focused more on the results of forecasts and their implications, academic research was mostly dedicated to perfecting the methodologies used in forecasting the demand for air transport.

The reviewed academic research can be divided into two subgroups based on the types of variables considered in determining demand for air transport services. These two types of variables are socio-economic variables and quality of service variables. The socio-economic variables most often considered include the population, income, employment characteristics, and wealth of the markets in question as well as the cost of air travel between those markets, represented by fares or yields. Quality of service determinants most often considered are the number of stops required to reach a destination, the time and frequency of flights, aircraft size, distance to airport, and others.

Some of the variables often used in institutional research for forecasting air traffic demand levels are: GDP, world exports, yields, income, and population. Industry research was generally less descriptive in regards to the forecasting methodology and considered mostly socio-economic determinants of air transport demand such as economic growth, oil prices, economic cycles, international exports, and imports of goods and services, fleet changes, etc.

Many studies employed econometric models relying on cross sectional and time series data. Academic research relied mostly on a gravity model (with demand between city pairs determined by the populations of the two cities), and one study concluded that it is hard to improve on the predictions of a simple gravity model. On one occasion, a study did a meta-analysis that integrated empirical findings of numerous other studies.

In this section, we describe baseline modeling of future demand and how alternative futures were forecasted. The baseline forecast was derived from the forecast described in the FAA FY03 annual forecast (FAA-APO-03-1, March 2003). In addition, alternative forecasts were generated to provide a basis for sensitivity analysis of results and because there is inherent uncertainty in any forecasting effort.

BASELINE MODELING OF FUTURE DEMAND

The FAA's long-range forecast for air transportation demand served as the baseline demand forecast presented in the report. The FAA uses the forecasts of RPMs and enplanements to provide the basis for forecasts of air transportation activity which are in turn, used to determine staffing levels and capital expenditures required to accommodate the growth of air transportation activity while maintaining a safe, secure, and efficient air transportation system. The forecasts are not capacity constrained, and assume that the FAA and the airlines will develop cost efficient solutions to mitigate any delay/congestion problems.

Aviation forecasters have known for years that demand for air transportation services, typically measured by RPMs (one revenue passenger flying one mile) or enplanements, is influenced by a number of factors. In particular, demand is positively related to income in that as income increases, a greater amount of income will be devoted to air travel. Demand is negatively related to price, typically measured by yield—passenger revenue divided by RPMs, in that as the price of flying rises, all other things being equal, the number of people flying will decrease. Additional structural changes to the industry such as the introduction of jet aircraft in the late 1950's or deregulation of fares and routes (October 1978) have over time altered the relationships between demand, income and price. In addition, some unique events (such as when U.S. carriers engaged in destructive fare wars in 1986 and 1992 or the events of September 11^{th}, 2001) have temporarily altered the relationship between demand and the economic variables mentioned above.

In general, the model used for developing the FAA domestic large air carrier forecast of traffic and yield relies upon a system of statistical and deterministic equations. The pivotal equations of the system relate RPMs and enplanements to three primary variables: real U.S. GDP, real U.S. personal consumption expenditures (PCE), and real yield (incorporating aviation user taxes and fees such as passenger facility charges). This analytical framework ties the domestic forecast model closer to projected changes in economic activity and reduces the number of subjective inputs. The general functional form of the equation systems is as follows:

RPMs = f (PCE, Yield)

Yield = f (RPMs, Sept 11)

Enplanements = f (GDP or PCE, Yield, Sept 11)

In the equation systems, there are a number of exogenous shift variables. The majority of these dummy variables are temporary in nature, attempting to account for short run disruptions to the long run relationships. The Sept 11 variable above is an example of such a variable. Another of these variables accounts for the impact to yields of Continental's low fare pricing experiment in East Coast markets during the 1994-1995 period, while another accounts for the impact to yields of the destructive fare war of 1992. Dummy variables are also used to account for the structural changes resulting from Southwest's expansion into East Coast markets and the introduction of the passenger segment fee in October 1997.

Economic Assumptions

The long-range economic forecasts that were used are based on the economic projections developed by the OMB and Global Insight, Inc.. OMB's projections for U.S. real GDP were used for the period 2002-2014 and then extrapolated to 2025. Global Insight's economic projections for inflation and for international economic growth extend through 2025. The economic forecasts were developed utilizing trend projections and assume that the economy experiences relatively stable growth throughout 2005-2025. Essentially, these projections represent the average of the possible paths that the U.S. and world economies could follow. Using trend projections assumes that: 1) no major shocks will occur (the rapid run-up in oil prices in 2001/02 and subsequent rapid decline in 2003/04 is assumed to be a temporary condition); 2) economic policies remain stable; 3) national and international markets do not experience dramatic shifts in either the supply or demand for economic goods and services. These long-term economic projections represent appropriate points from which to evaluate the effects of variations about the mean of expected values of various activity measures, transportation services, or FAA workload measures.

Real GDP

The U.S. economy is expected to grow at a moderate rate during the 23-year forecast period. Growth in real GDP, adjusted for price changes and expressed in 1996 dollars, is projected to average 3.2% annually for the immediate 12-year forecast period from 2002 to 2014, and average 3.1% annually over the extended forecast period (2014 to 2025). This is comparable to the historic rate of growth of 2.9% between 1974 and 2000.

International economic growth is expected to grow at rates comparable to those of the U.S. during the 23-year forecast period. World real GDP is projected to average 3.3% annually for the immediate 12-year forecast period and average 2.8% annually over the extended 11-year forecast period. These rates of growth are comparable to the historic rate of growth of 2.8% between 1980 and 2000.

Consumer Price Index

Inflation is not expected to return to the high rates experienced during the latter half of the 1970s and early 1980s (8.7% annual growth between 1972 and 1982) during the entire 23-year forecast period. The opinion of the major economic forecasting services is that there will be little upward pressure from real wage rates and commodity prices, and that the Federal Reserve is committed to controlling inflation while providing for sufficient growth in the money supply to ensure growth in output. The consumer price index is projected to increase at an average annual rate of 2.7% annually during the 23-year time period, 2.2% during the immediate period, but increasing to 3.3% over the extended forecast period.

Operational Variables

The long-range forecasts of various operational variables discussed below are, for the most part, a continuation of the trends discussed in greater detail in *FAA Aerospace Forecasts: Fiscal Years 2003-2014*. As with the economic projections, these forecasts reflect an average trend of the possible paths that the various operational variables could follow.

Air Carrier Passenger Yield

The forecast assume that real domestic passenger yields (expressed as revenue per passenger mile) will continue its historical long-term gradual downward trend. Real domestic passenger yields are projected to decline by 0.9% annually over the 23-year period. The downward trend in real domestic yields is based on the assumptions of continued strong competition in the industry, and continued improvements in efficiency and productivity.

Average Seats per Mile

The average number of seats per mile for the U.S. domestic airline fleet is projected to grow modestly over the course of the 23-year forecast period. In the near term (through 2007), the retirement of older, smaller aircraft coupled with large numbers of regional jet deliveries will result in a decrease in the average number of seats per mile. Beyond 2007 most of the smaller hush-kitted stage-2 aircraft will have either been replaced with generally larger stage-3 aircraft or retired and it is expected that deliveries of the larger commercial jets will return to more historic levels. Over the 23-year forecast period, the average seats per mile for the domestic fleet is projected to increase just 0.4 seats per year, from 125.9 in 2002 to 134.6 in 2025.

Load Factor

Domestic load factor is projected to remain at its current historical high levels throughout the remainder of the immediate and extended forecast periods. During the past several years, airline scheduling policies have allowed air carriers to rapidly adjust capacity levels to more closely correspond to changes in passenger demand; this has enabled the airlines to push up load factors to all-time highs. It is expected that present fleet plans will provide capacity levels that should maintain the air carrier load factors between 71% and 75% throughout the forecast period.

As in domestic markets, the wide range of aircraft capable of international flight also allows U.S. airlines to adjust their international capacity levels to changing levels of demand. The international load factor is also forecast to remain relatively stable during the 23-year forecast period, increasing slightly from 74.5% in 2002 to 76.5% in 2025.

Demand Forecast

Air carrier demand, as measured by domestic RPMs, is projected to continue to grow faster than the general economy. For the period 2002 to 2014, domestic RPMs are forecast to increase at an average annual rate of 3.9% compared to a 3.2% annual growth rate in real GDP. Over the extended forecast period (2014-2025), domestic RPMs are projected to increase at an average annual rate of 3.6% compared to real GDP growth of 3.1% annually.

International RPMs have historically grown at faster rates than domestic RPMs. The baseline demand forecast reflects a continuation of this trend. International RPMs are projected to increase at an average annual rate of 4.9% during 2002 to 2014. Over the extended forecast period (2014-2025), international RPMs are forecast to increase at an average annual rate of 4.3%. Figures 3-11 and 3-12 summarize the baseline demand forecast results.

Figure 3-11. Baseline Demand Forecast, Domestic Statistics

Year	RPMs (Billions)	Load Factor Percentage	Seats per Aircraft	Real Yield (2002 $)
2000	512.3	70.5%	129.6	$ 0.1470
2015	780.8	74.5%	128.5	$ 0.1084
2025	1,116.3	75.0%	134.6	$ 0.0964

Figure 3-12. Baseline Demand Forecast, International Statistics

Year	RPMs (Billions)	Load Factor Percentage	Seats per Aircraft	Real Yield (2002 $)
2000	181.8	76.0%	230.6	$ 0.1095
2015	293.3	76.6%	229.4	$ 0.0909
2025	446.6	76.5%	231.7	$ 0.0882

DEMAND CURVES FOR 2015 AND 2025

In the baseline forecast discussed previously, domestic RPMs are projected to reach 780.8 billion in 2015 and 1.116 trillion in 2025. Real yields (measured in constant 2002 dollars) are projected to reach 10.84 cents and 9.64 cents for 2015 and 2025, respectively. For the international air travel market for 2015 and 2025, RPMs are projected to reach 293.3 billion and 446.6 billion, and real yields are projected to reach 9.09 cents and 8.82 cents, respectively.

We used forecasted RPMs and equilibrium fare yields in 2015 and 2025 to generate the demand curves shown in Figures 3-13 through 3-18. These figures show the assumed relationship between airline yields and the demand for air travel. Note that the demand curves reflect, by assumption, constant price elasticities. For the domestic markets, we allowed the yield elasticity to vary between -0.53 and -1.27. The inelastic demand curves reflect the short-run yield elasticities from the FAA model (discussed previously) and an assumed 75%-25% split of seats offered to the public between network and low-cost carriers, respectively. The elastic demand curves reflect the long-run yield elasticities from the FAA model and the same assumed split between categories of carriers. For the international markets, a single yield elasticity of -0.79 was used. This value is derived from a recent survey of air travel demand elasticities by David Gillen et al. (median elasticity values for studies scoring greater than or equal to 12 points).[98] The weighted average yield elasticity reflects a 68%-32% split among international leisure travelers and international business travelers, respectively.

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[98] Air Travel Demand Elasticities: Concepts, Issues, and Measurement, David W. Gillen, William G. Morrison, and Christopher Steward, Wilfred Laurier University, 6 November 2002, p. 61. Table 5-1.

Figure 3-13. Domestic Air Travel in 2015 (Inelastic Demand)

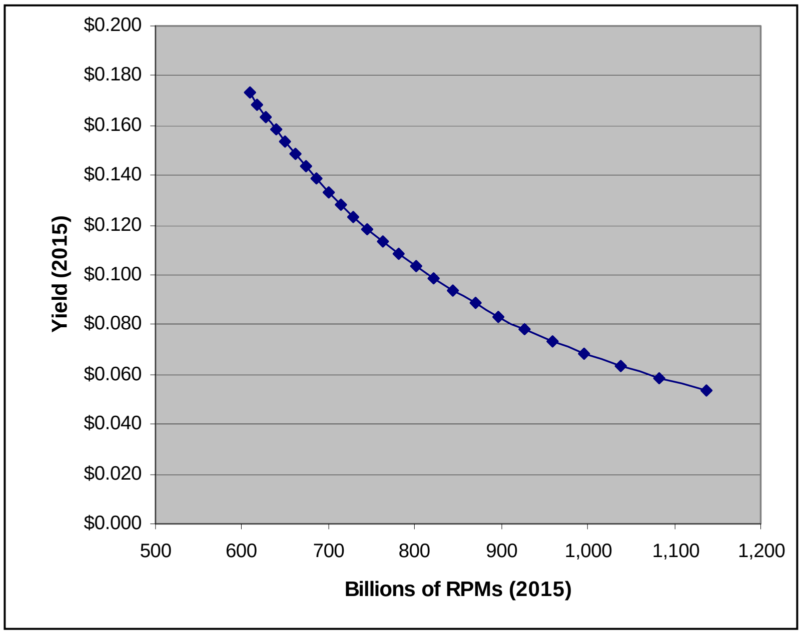


Figure 3-14. Domestic Air Travel in 2015 (Elastic Demand)

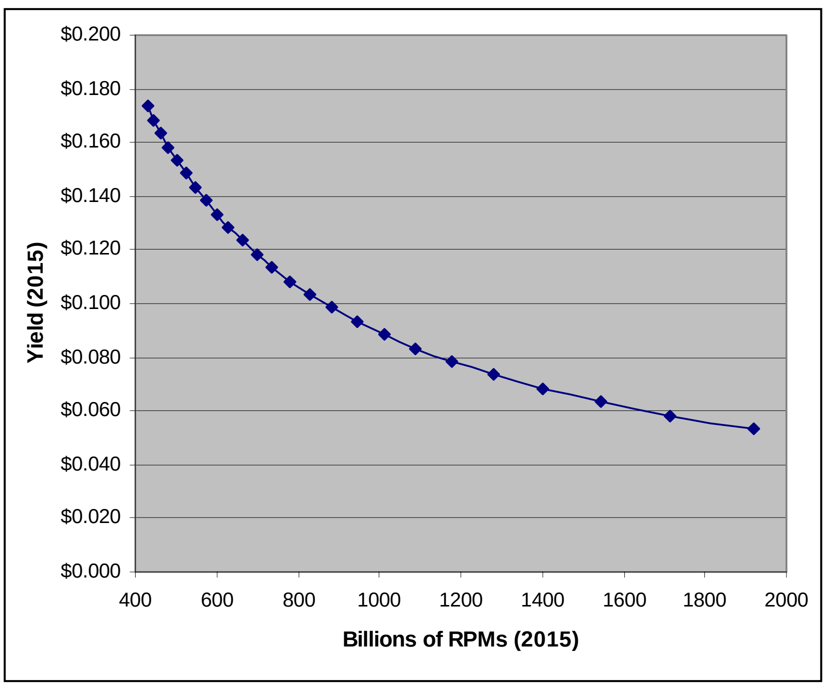


Figure 3-15. International Air Travel Demand in 2015

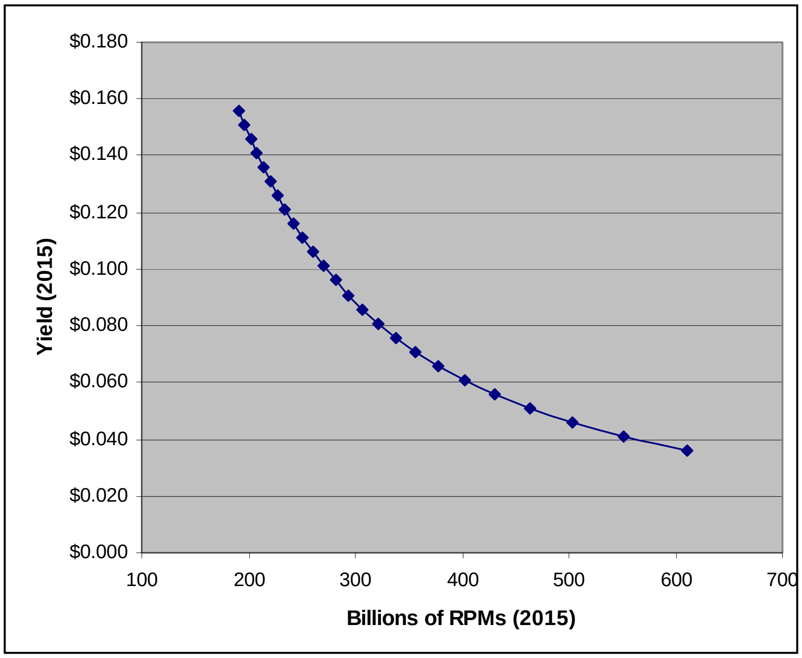


Figure 3-16. Domestic Air Travel in 2025 (Inelastic Demand)

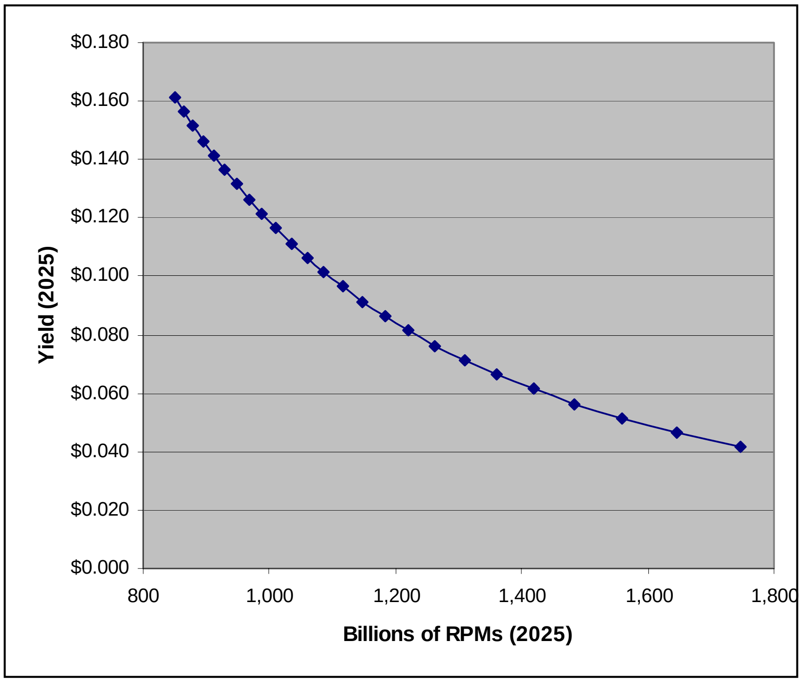


Figure 3-17. Domestic Air Travel in 2025 (Elastic Demand)

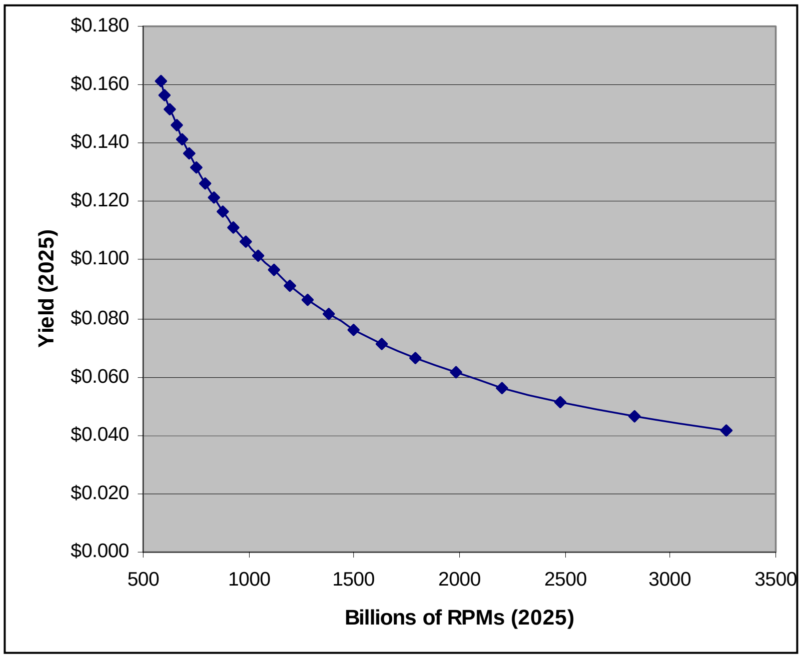
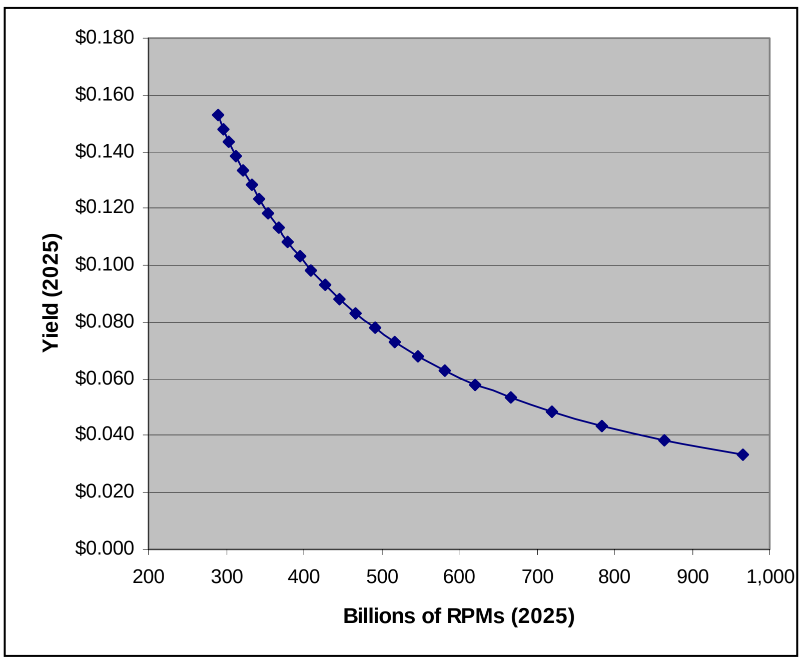


Figure 3-18. International Air Travel Demand in 2025



ALTERNATIVE FORECASTS

The high and low alternative futures for growth in passenger demand for domestic RPMs were developed using Monte Carlo simulation techniques. This technique allowed the calculation of a range of alternatives to the baseline forecast based on historical data and relationships for the most important factors driving demand growth.

The two principal factors governing year to year changes in the demand for domestic RPMs are changes in real national income, or real GDP, and changes in the real cost of air travel, represented by changes in the real airline average yield.[99] Thus, like for most commodities, changes in the demand for air travel are principally affected by changes in income and changes in price. The Monte Carlo simulation is built up from repeated random annual changes in real GDP and real yields, which in turn drive year to year growth in RPMs over the twenty year forecast period of 2005 to 2025.

The model linking annual percentage changes in the demand for RPMs to annual percentage changes in real GDP and real yield is based upon the parameters estimated in the FAA's baseline forecast model. That model is a complex system of multiple simultaneous equations, and the Monte Carlo simulation model is necessarily a simplification of that system. In the simulation, the annual percentage change in the demand for RPMs is equal to the annual percentage change in real GDP minus 0.531 times the annual percentage change in the real yield. Thus, the relationship between annual percentage change in domestic RPMs and the two underlying drivers can be shown as:

$$\%\Delta RPM_t = \%\Delta GDP_t - 0.531 * \%\Delta REALYIELD_t$$

To complete the simulation model, underlying processes for annual percentage changes in real GDP and real average yield were identified. These are based on historical data and on the FAA's treatment of some aspects of these historical data.

For real GDP, a mean annual percentage change of 3.12% was used for 2005 to 2025. This value is a smoothing of the values used for the FAA extended baseline forecast, which assumes 3.14% annual growth for 2005 to 2015 and 3.10% annual growth for the remaining years. A standard deviation of 2.0% was used for annual percentage changes in real GDP, based on the general behavior of the series for real GDP data starting with the mid 1970s and ending with the year 2000. Thus, each annual percentage change in real GDP used in the simulation of RPM demand growth is a random sample from a normal distribution with a mean of 3.12% and a standard deviation of 2.0%.

For real yield annual percentage changes, a mean value of –1.26% is used. This value is a smoothing of the values generated by the FAA baseline forecast model, which projects real yields falling 1.35% annually from 2005 to 2015 and then falling more slowly through 2025 at a rate of 1.17% annually. In the Monte Carlo simulation model, the standard deviation for real yield annual percentage changes is set at 3.48%, based on the value calculated from annual data for 1987 to 2000. Thus, each annual percentage change in real yield used in the simulation of domestic RPM demand growth is a random sample from a normal distribution with a mean of –1.26% and a standard deviation of 3.48%.

While there is no strong evidence of autocorrelation in the data for annual percentage changes in real yield and annual percentage changes in real GDP, the two series (evaluated on a fiscal year basis) are themselves positively correlated. The correlation coefficient of 0.452 was estimated from annual data for 1987 to 2000, and was incorporated into the Monte Carlo simulation model.

Figure 3-19 is a schematic depiction of the model used to generate the Monte Carlo simulated trials. Simulations were created using the Analytica software package, and 10,000 simulated trajectories or times series of domestic RPMs were generated. The median domestic RPM trajectory from these simulated trajectories closely tracks the FAA's baseline forecast for domestic RPMs from 2005 to

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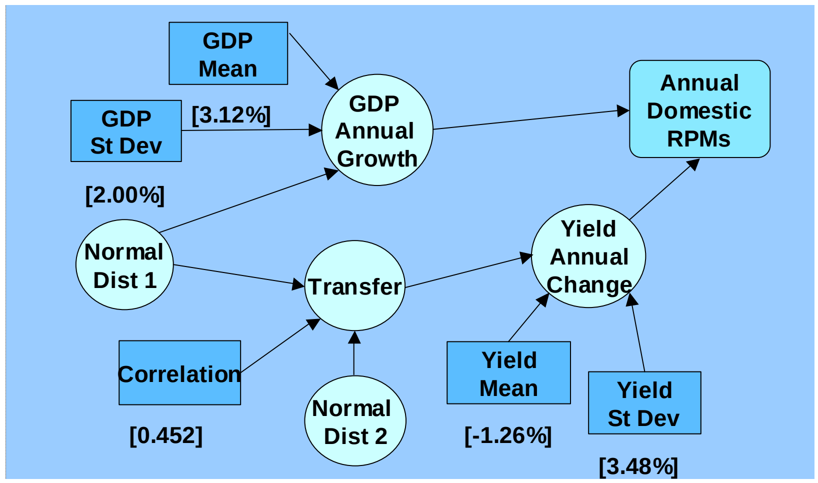
[99] "Average yield" is the average revenue received by airlines per passenger mile flown. It represents an average money cost to passengers of flying a single mile.

2025. The high alternative path or future for domestic RPMs is at the 90th percentile of the 10,000 simulations, and the low alternative path or future is at the 10th percentile. It is important to note that these alternatives were developed in order to have data-driven values that could be used for sensitivity assessments of the future impact and requirements for NAS capacity. However, the range between the high and low alternatives in any given year between 2005 and 2025 does not represent a "confidence interval" around the baseline forecast values in the usual statistical meaning of the term.

Figure 3-19. Schematic Depicting Model Used to Generate Monte Carlo Simulation



Figures 3-20 and 3-21 show the results of the Monte Carlo simulation. The percentage changes by which the 90th percentile forecast and the 10th percentile forecast differed from the baseline domestic forecast were applied against the baseline international forecast to generate high and low forecasts for international demand in 2015 and 2025.

Figure 3-20. Forecasts for 2015 (Billions of RPMs)

	Low (10th Percentile)	Baseline	High (90th Percentile)
Domestic demand	712.2	780.8	831.8
International demand	267.5	293.3	312.5

Figure 3-21. Forecasts for 2025 (Billions of RPMs)

	Low (10th Percentile)	Baseline	High (90th Percentile)
Domestic demand	998.1	1,116.3	1,245.0
International demand	399.3	446.6	498.0

FUTURE NAS CAPACITY

Although the focus of the study is on assessing the NAS performance shortfall if nothing is done to address the forecasted demand for air travel, we recognize that, at least in the near term, plans to enhance NAS capacity do exist. Among these plans, the most prominent is the OEP.[100] This section briefly summarizes the OEP and the components within it that were modeled to produce an estimate of future NAS capacity.

We wish to stress that the intention in this study is not to conduct a complete benefits assessment of the OEP; such an assessment is precluded by time and budget limitations. Beside the resources

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[100] http://www.faa.gov/programs/oep/

constraints, we do not want to duplicate previous work done by others, such as MITRE. Our motivation for conducting this first-order analysis of future NAS capacity is to ensure that the overall study is based on conservative assumptions—if we were to ignore the additional capacity due to the OEP, the SEDF study would incorrectly produce an artificially high estimate of the NAS performance shortfall.

Thus, while the analysis of future NAS capacity is based substantially on the OEP, the SEDF study should not be considered as a comprehensive evaluation of the benefits of the OEP. To cite one important example, the SEDF study methodology is based on airlines scheduling practices that are based on good weather NAS capacity. This means that anything in the OEP related to improving capacity or throughput during bad weather conditions is not relevant and thus not modeled in the SEDF study.

MODELED IMPROVEMENTS IN INFRASTRUCTURE, TECHNOLOGY AND PROCEDURES

The OEP considers a variety of procedural, technological and infrastructure improvements for enhancing future NAS capacity. The OEP divides these concepts into four categories:

- Improving arrival/departure rates
- Improving en-route congestion
- Increasing airport capacity in bad weather*
- Dealing with en-route severe weather*

* NOTE: Since the SEDF study is conducted under long-range planning assumptions under good weather, we do not consider the technologies and procedures that improve capacity under reduced conditions and bad weather.

IMPROVING ARRIVAL/DEPARTURE RATES

There are several enhancements listed in the OEP that, if implemented, should improve runway capacity at airports. The SEDF study models the following improvements:

- Runway additions and improvements
- Filling gaps in arrival and departure streams
- Coordinating efficient surface movement

Runway Additions and Improvements

The list of airports with runway improvements in the OEP represents the latest version of airports that have started, or are most likely to initiate, these physical enhancements. Figure 3-22 lists those airports.

Figure 3-22. Airports Receiving Runways by 2015	
Denver (DEN)	Boston (BOS)
Miami (MIA)	Cincinnati (CVG)
Orlando (MCO)	St. Louis (STL)
Houston (IAH)	Atlanta (ATL)
Minneapolis (MSP)	Washington (IAD)
Cleveland (CLE)	Seattle (SEA)

Based on the data provided in the OEP, the new airport plates, and results from the LMINET Capacity Model, we were able to estimate the new FAA-style Pareto curves of maximum capacity for these airports. It is important to note that in some cases the airport capacity may only increase under certain weather conditions. Therefore, under the good weather assumption in this study, some of these airports may not have a higher capacity in the future scenario years. The study also assumes there are no additional runway improvements after 2015 (i.e., the runway capacities in 2025 are identical to those in 2015).

Filling Gaps in the Arrival and Departure Streams

Decision support tools can improve controllers' ability to improve sequencing plans and optimize runway balancing. The implementation of the Traffic Management Advisor (TMA) and the passive Final Approach Spacing Tool (pFAST) will provide an increased arrival capacity by optimizing the sequencing of aircraft types into an airport. For the SEDF analysis, we assume that TMA and pFAST are deployed and in effect at all 102 LMINET airports by 2015. The FAA estimates that the implementation of these technologies will improve an airport's arrival capacity by 5%. The results we obtain from modeling these tools using the LMINET Capacity Model are very similar.

Coordinating Efficient Surface Movement

Efficient movements at the airport surface could significantly increase taxiing and runway capacity. Improved communication and surveillance can reduce taxiing times and improve departure streams.

The study team assumes the fusion of Automatic Dependent Surveillance Broadcast (ADS-B) with Airport Surface Detection Equipment (ASDE) for the 2015 and 2025 analyses. Furthermore, we assumes an improved Surface Management System (SMS) will improve taxiing procedures. The study models these technologies in two ways. First, we model that departures are conducted more efficiently by these utilizing these tools. Specifically, we run the model such that small, large and heavy aircraft are sequenced and depart in an optimized manner, much like how TMA functions on the arrival side. Secondly, we assume that any increase in runway capacity, whether by technologies or increased or improved runways, will result in a proportional increase in taxiing capacity. That is, if the total maximum number of operations in an hour for a given airport increases from 100 to 120, then we model the taxi capacity to also increase 20% at that airport.

Modeling Results for Improving Arrival/Departure Rates

We used the LMI Capacity Model to develop factors, as shown in Figure 3-23, for the benefits of the technologies discussed above in the "Filling Gaps in the Arrival and Departure Streams" and "Coordinating Efficient Surface Movement" subsections. These improvement factors were then applied to the baseline capacities of each of the 102 airports according to each airport runway configuration.

Figure 3-23. Arrival/Departure Improvements Due to OEP Technology in VFR Conditions

Operating Value	Percentage Improvement
Maximum arrivals	4%
Minimum arrivals	4%
Maximum departures	1%
Minimum departures	4%

There are other technologies listed in the OEP under the section of improving arrival and departure rates. They include redesigning terminal and airspace routes, using crossing runway procedures, and decreasing separation standards for wake turbulence for closely-spaced parallel runways. While it is possible many of these changes will be in effect by 2015, some of these concepts are quite speculative. Regardless of the prediction of whether they would actually be fielded by 2015, the time and budget constraints on the analysis precluded the kind of airport-specific study we would need to undertake to capture the effects of these concepts.

IMPROVING EN ROUTE CONGESTION

For improving the en-route congestion, the OEP considers several potential concepts for reducing the strain on the system. We consider the two that we believe are both likely to occur and have the most dramatic effect when implemented:

- Reducing voice communications
- Reducing vertical separations

Reducing Voice Communications

The reliance on voice communications between pilots and controllers can cause some inefficiency through a variety of imperfect human actions and responses. A voice system that is supplemented by the Controller-Pilot Data Link Communications (CPDLC) would provide much of the necessary information in a reduced amount of time, thereby making en-route capacity higher. We assume implementation of CPDLC Build 1A by 2015.

Reducing Vertical Separations

The implementation of the Reduced Vertical Separation Minimum (RVSM) will add six more flight levels at high altitudes. The increase in flight levels will help Air Traffic Control and reduce delays, thereby increasing fuel savings. There are currently seven flight levels between 29,000 and 41,000 feet. We model the addition of these six, making a flight level at every 1000 feet and assume that all aircraft that fly above 29,000 feet will be RVSM compliant by that time.

Modeling Results for Improving En Route Congestion

We translate the improvement due to CPDLC and RVSM into an increase in en route sector capacity of 30%. This number was based on results of prior studies which modeled the decrease in en route controller workload to derive an estimate of sector capacity increase.[101, 102]

There are some planned en-route changes and potential technologies described in the OEP that we do not incorporate in this study. These include splitting and re-stratifying sectors based on changes in demand, collaborating the Reroute Advisory Team (RAT) and Route Management Tool, and accommodating user preferred routing by deploying the User Request Evaluation Tool (URET). We believe that we cannot model these concepts in any meaningful way given time and resources limitations.

RESULTS: FUTURE NAS PERFORMANCE AND SHORTFALL ESTIMATES

At this point, we have described the process we follow to forecast the future demand for air travel and how we model future NAS capacity. We have also described, in the section entitled “Constrained Schedule Builder,” how we eliminate flights from the future flight schedule in order to resolve the demand-capacity imbalance. We are now ready to examine the results of the SEDF analysis, which comprise the number of foregone flights, the number of foregone RPMs, the

[101] FAA CPDLC Benefits Analysis, presentation to the Joint Research Council, April 15, 2003.

[102] Leiden, K., Kopardekar, P., and Green, S., “Controller Workload Analysis Methodology to Predict Increases in Airspace Capacity,” AIAA 2003-6808, November 2003.

remaining delay in the system. The presentation of these NAS performance metrics is followed by an explanation and results of the economic valuation of the shortfall.

PERFORMANCE RESULTS

Foregone Flights and RPMs

The following section presents the lost RPMs in three market segments. Figures 3-24 through 3-26 show the percentage reductions in flights and RPMs necessary to adjust unconstrained demand to match capacity constraints at the 102 LMINET airports and the various enroute sectors.

Figure 3-24 reports these reductions from the baseline forecast for unconstrained demand. In the domestic arena for 2015, air system capacity constraints lead to a 6.3% reduction in total flights and a 4.9% reduction in RPMs. In the same year, international flights are reduced 1.1% and RPMs are reduced nearly 1%, while GA flights are reduced 4.6% and GA RPMs are reduced 3%. Without additional capacity, domestic flights in 2025 are reduced nearly 16% from the baseline level of unconstrained demand, and RPMs are reduced nearly 15%. International flights are reduced nearly 4% in 2025, and international RPMs are reduced 1.6%, while GA flights and RPMs are reduced 9.1% and 6.2%, respectively.

The impacts of insufficient capacity on activity are less severe in the lower alternative forecast for unconstrained demand, as shown in Figure 3-25. For the higher alternative forecast, more significant reductions from unconstrained levels of demand are necessary, as shown in Figure 3-26.

Figure 3-24. Percentage Reductions of Flights and RPMs (Single Scenario Day) Baseline Demand Forecast

	Domestic Air Carrier		International Air Carrier		General Aviation	
	Flights	RPMs	Flights	RPMs	Flights	RPMs
2015	6.34%	4.86%	1.13%	0.75%	4.55%	2.96%
2025	15.75%	14.54%	3.90%	1.59%	9.14%	6.21%

Figure 3-25. Percentage Reductions of Flights and RPMs (Single Scenario Day) Low-End Demand Forecast

	Domestic Air Carrier		International Air Carrier		General Aviation	
	Flights	RPMs	Flights	RPMs	Flights	RPMs
2015	4.19%	2.83%	0.31%	0.045%	2.70%	1.88%
2025	11.69%	10.16%	1.70%	0.41%	7.41%	4.69%

Figure 3-26. Percentage Reductions of Flights and RPMs (Single Scenario Day) High-End Demand Forecast

	Domestic Air Carrier		International Air Carrier		General Aviation	
	Flights	RPMs	Flights	RPMs	Flights	RPMs
2015	7.86%	6.55%	1.42%	0.78%	4.76%	3.29%
2025	18.15%	18.80%	3.86%	1.69%	9.19%	6.93%

Delay

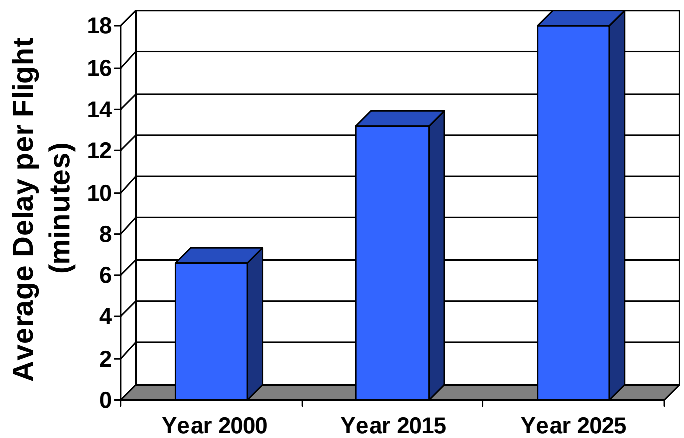
The LMINET queuing model provides statistics that help generate the constrained schedule. The unconstrained demand is fed into the model, and the airport queues are computed. Recall that we generate the constrained demand based on the concept of delay tolerance. Specifically, we assume that for the major airports, delays can grow no larger than those experienced at the peak demands for a 2000 schedule under universally good weather—i.e., those peak delays, strictly due to demand and not weather, are the largest allowable tolerance in a future year. For those airports whose delays are less significant (typically smaller, less congested airports), we stipulate that their delays cannot grow larger than the average delay experienced in 2000 at the 31 large hub airports.

Thus, while the SEDF method caps delay by eliminating flights, average delay will still rise significantly in 2015 and 2025 scenarios. In particular, delay during the off-peak hours will grow from their minimal 2000 levels until they reach the maximum delay allowed. However, for peak hours at the major airports, delays will increase relatively little as they are already very close to capacity and the imposed delay tolerance. We stress that a significant portion of the demand is shed in the constrained schedule and that is the major source of economic loss. The residual delay imposes an additional cost on airlines and passengers via the increased variable operating costs incurred and the value of lost passenger time.

The 2000 delay is based on results of the LMINET model using ETMS data for flight data from August 28, 2000 under the assumption of universally good weather. Figure 3-27 shows the sum of the average arrival delay and average departure delay. For the 2000 demand, the sum of the average delays was 6.6 minutes. In 2015, this sum was 13.2 minutes; and in 2025, it was 18.0 minutes.

Note that these average delays are only for operations at the 102 LMINET airports. However, while these do not represent all of the airports in the NAS, they do represent almost all the delay experienced. Also, because we used a relatively busy day in the analysis, these calculated average delays are higher than the average delays that the NAS would experience throughout a year. Finally, we note that the model uses queuing theory as the basis for the delay calculations. Thus when demand is close to airport capacity, then the resultant delay will be large and even a small increase in demand will result in a big increase of delay. This is why delays ramp up quickly in the SEDF estimates for 2015 and 2025 corresponding to the increased level of demand forecast for those future years.

Figure 3-27. Average Delay per Flight with Constrained Demand



VALUE OF LOST THROUGHPUT

In chapter 2, the section titled “Assessing a Shortfall between Demand and Capacity” presented the method for valuing the losses to consumers of passenger services. Using the data on capacity constraints and flights foregone described in the previous section, this method can be applied starting with the demand curves depicted in Figures 3-13 through 3-18 to estimate the cost to consumers of forgoing future expansions of NAS capacity. For international RPMs, we used a single demand curve for 2015 and a single demand curve for 2025, each based on an assumed elasticity of –0.79. For demand for domestic RPMs, which makes up the larger share of passenger impacts, we used two demand curves for each benchmark year, to reflect the inherent uncertainty in these estimates. For both 2015 and 2025, we used a demand curve based on a relatively inelastic demand elasticity of –0.53 and a relatively elastic demand elasticity of –1.27.

In the section entitled “Performance Results,” we reported the lost RPMs in three market segments. Using the demand curves developed previously, it is possible to estimate the losses in consumer surplus associated with future capacity constraints.

For the domestic and international market segments, the calculations are fairly straight-forward. Because we do not have a demand curve for the GA market, we approximated the loss by multiplying the reduction in GA passenger miles times the domestic yield in each of the two years of interest. The results are shown in Figure 3-28 through 3-30. All dollar figures are reported in year 2002 constant dollars.

In Figure 3-28, we report the percentage increase in average yield necessary to constrain the quantity of RPMs demanded under the baseline demand forecast to a level that could be accommodated by a more constrained national airspace system. We do this for each of the domestic market demand elasticities and for the international market demand elasticity. This percentage change in yield is reported for both 2015 and 2025. Using the methodology presented in section 2 of this report, we then calculate the dollar amount of consumer surplus lost to passengers due to this necessary increase in average yields. Finally, Figure 3-28 reports the losses to GA passengers in the absence of new system capacity.

Figures 3-29 and 3-30 report the identical calculations for the low alternative demand forecast and the high alternative demand forecast respectively.

Figure 3-28. Consumer Surplus Calculations, Baseline Demand Forecast

Market Segment of Interest	Relevant Yield Elasticity	2015		2025	
		Yield Increase[103]	Lost Consumer Surplus	Yield Increase	Lost Consumer Surplus
Domestic upper bound	-0.53 (inelastic)	9.86%	$8.14 billion	34.5%	$34.44 billion
Domestic lower bound	-1.27 (elastic)	4.00%	$3.30 billion	13.2%	$13.14 billion
International	-0.79	0.96%	$0.25 billion	2.05%	$0.80 billion
General aviation	N/A	N/A	$0.07 billion	N/A	$0.18 billion

Figure 3-29. Consumer Surplus Calculations, Low Demand Forecast

Market Segment of Interest	Relevant Yield Elasticity	2015		2025	
		Yield Increase	Lost Consumer Surplus	Yield Increase	Lost Consumer Surplus
Domestic upper bound	-0.53 (inelastic)	5.57%	$4.24 billion	22.40%	$20.5 billion
Domestic lower bound	-1.27 (elastic)	2.29%	$1.74 billion	8.80%	$8.04 billion
International	-0.79	0.06%	$0.01 billion	0.52%	$0.18 billion
General aviation	N/A	N/A	$0.03 billion	N/A	$0.10 billion

Figure 3-30. Consumer Surplus Calculations, High Demand Forecast

Market Segment of interest	Relevant Yield Elasticity	2015		2025	
		Yield Increase	Lost Consumer Surplus	Yield Increase	Lost Consumer Surplus
Domestic upper bound	-0.53 (inelastic)	13.63%	$11.9 billion	48.1%	$52.3 billion
Domestic lower bound	-1.27 (elastic)	5.48%	$4.78 billion	17.8%	$19.4 billion
International	-0.79	1.00%	$0.28 billion	2.18%	$0.95 billion
General aviation	N/A	N/A	$0.09 billion	N/A	$0.27 billion

As explained previously, it is possible to decompose the consumer surplus loss. Taking the domestic air travel market in 2025 with the more price elastic demand curve as an example, we observe that approximately 224 million one-way air trips will be foregone in the capacity-constrained environment (a significant fraction of the nearly 1.3 billion one-way air trips projected to occur in the unconstrained environment). In addition, for those travelers who would not be not priced out of

[103] The demand curves reflect constant elasticities of air travel demand with respect to fares. Consequently, the yield change will not be the same as would be estimated by simply dividing the yield elasticity into the RPM reduction.

the constrained air travel market, the average round-trip airfare will increase from approximately $166 to $193.

As is readily apparent, the principal effects of capacity constraints are manifested in the domestic air travel market. The impacts on international air travel and GA are small relative to the large loss of consumer surplus in the domestic market. Furthermore, the estimated loss in the domestic air travel market has a wide range, because of uncertainty about the correct yield elasticity. For this reason, the reader is cautioned against relying too heavily on the $34.4 billion estimate (in the baseline demand forecast scenario, Figure 3-28) because it is likely that demand will be more price elastic in 2025, particularly if it has been apparent for some time that congestion has been increasing and substitutes are more readily available.

COST OF DELAY

To estimate the economic cost of flight delay, we multiply incremental hours of delay by aircraft variable operating costs (VOC) and the value of passenger time, both expressed on an hourly basis. VOC includes: aircraft fuel and oil costs, flight deck crew and flight attendants, and aircraft and engine maintenance. We believe that VOC is the correct measure because the SEDF methodology caps delay at peak levels experienced during 2000 and, consequently, increases in delay are relatively small. The FAA states that "the capital cost of the airplane are usually not included as benefits for projects involving small to moderate reductions in delay, in that such delay savings will generally not affect fleet allocations by operators." [104] To be consistent, the valuation of small to moderate increases in delay should not include capital costs. The FAA specifies[105] variable operating costs, aircraft capacity, utilization factors, and the value of passenger time for various categories of carriers and aircraft as shown in Figure 3-31.

Figure 3-31. FAA Critical Values

Factor	Air Carriers w/o Commuters	Commuters	General Aviation
Variable operating costs (per hour)	$3,043	$608	$199
Passenger capacity (seats)	158.9	41.7	5.4
Load factor	69.1%	57.9%	49.5
Value of passenger time (per hour)	$26.70	$26.70	$31.10

Using these data and the incremental annual arrival and departure delays previously discussed as performance results, we can estimate an annual economic loss associated with the increase in delays as capacity constraints begin to bind at more and more airports. The results are shown in Figures 3-32 through 3-37.

[104] FAA Airport Benefit-Cost Analysis Guidance, Office of Aviation Policy and Plans, Federal Aviation Administration, December 15, 1999, p. 54.
[105] http://api.hq.faa.gov/economic/EXECSUMM.PDF

Figure 3-32. Annual Economic Loss from Incremental Delay in 2015, Baseline Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	1,924,718	877,225	444,306	603,188
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC ($ million)	$3,060	$2,669	$270	$120
Annual passenger delay ($ million)	$2,908	$2,572	$286	$50
Grand total ($ million)	**$5,968**	**$5,241**	**$557**	**$170**

Figure 3-33. Annual Economic Loss from Incremental Delay in 2025, Baseline Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	3,748,341	1,667,456	817,468	1,263,417
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC ($ million)	$5,823	$5,074	$497	$251
Annual passenger delay ($ million)	$5,520	$4,888	$527	$105
Grand total ($ million)	**$11,343**	**$9,962**	**$1,024**	**$356**

Figure 3-34. Annual Economic Loss from Incremental Delay in 2015, Low Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	1,229,679	575,250	292,393	362,037
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC ($ million)	$2,000	$1,750	$178	$72
Annual passenger delay ($ million)	$1,905	$1,686	$188	$30
Grand total ($ million)	**$3,905**	**$3,437**	**$366**	**$102**

Figure 3-35. Annual Economic Loss from Incremental Delay in 2025, Low Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	2,968,580	1,335,404	658,246	974,929
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC ($ million)	$4,658	$4,064	$400	$194
Annual passenger delay ($ million)	$4,420	$3,915	$424	$81
Grand total ($ million)	**$9,078**	**$7,979**	**$825**	**$275**

Figure 3-36. Annual Economic Loss from Incremental Delay in 2015, High Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	2,167,513	993,878	502,292	671,342
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC($ million)	$3,463	$3,024	$305	$134
Annual passenger delay ($ million)	$3,293	$2,914	$324	$56
Grand total($ million)	**$6,757**	**$5,938**	**$629**	**$189**

Figure 3-37. Annual Economic Loss from Incremental Delay in 2025, High Demand Forecast				
	All Aircraft	Air Carrier	Commuter	General Aviation
Incremental hours of delay	3,735,695	1,686,245	835,578	1,213,872
VOC ($ per hour)		$3,043	$608	$199
Passenger delay cost ($ per hour)		$2,932	$645	$83
Annual VOC($ million)	$5,881	$5,131	$508	$242
Annual passenger delay ($ million)	$5,583	$4,943	$539	$101
Grand total ($ million)	**$11,464**	**$10,075**	**$1,047**	**$342**

TOTAL ECONOMIC VALUATION RESULTS

In this section, we summarize the loss of consumer surplus and the incremental costs associated with delay for the two target years that we explicitly analyzed. We also report an estimate of the cumulative impact on consumer welfare over the decade from 2015 to 2025 for the baseline, high, and low demand forecasts. Because of the complexities and uncertainties associated with the domestic market demand elasticity and the importance of this value for the consumer surplus calculations, the lower bound for the demand elasticity estimates is used for the reported consumer surplus losses in the domestic air travel market. This choice was made in order to provide a conservative estimate. All dollar values are in constant, undiscounted 2002 dollars.

In the tables that follow, consumer surplus losses in the domestic commercial air travel market, the international commercial air travel market, and GA passenger markets are reported together with passenger costs associated with increases in delay. Separate from these NAS capacity shortfall effects on consumers, we report the increased annual operating costs for airlines in the capacity constrained environment. These increased operating costs would be passed along to passengers to the extent possible. As such, these costs may make up some of the increase in average yield necessary to reduce RPMs demanded to a level consistent with the capacity constraints. This increase in average yield leads to an associated reduction in consumer surplus in the capacity-constrained world compared to the unconstrained world.

Results for Baseline Demand Forecast

Figure 3-38 reports losses and costs to passengers in 2015 and 2025 due to the NAS capacity shortfall under the baseline demand forecast. These costs range from $6.5 billion in 2015 to $19.6 billion in 2025. The area of largest impact is the loss from consumer surplus in the domestic air transportation market.

Figure 3-38. Summary of Passenger Impacts, Baseline Demand Forecast

Category	2015	2025
Loss of consumer surplus in domestic air travel market (billion)	$3.30	$13.14
Loss of consumer surplus in international air travel market (billion)	$0.25	$0.80
Value of GA passenger miles lost (billion)	$0.07	$0.18
Cost of incremental passenger delay experienced (billion)	$2.91	$5.52
Total (billion)	**$6.53**	**$19.6**

Under the baseline demand forecast, airlines also face operating cost increases due to higher levels of delays relative to the year-2000 benchmark. For the baseline forecast of future demand for RPMs, the additional costs to airlines are reported in Figure 3-39. These range from $3.1 billion in 2015 to $5.8 billion in 2025.

Figure 3-39. Summary of Airline Impacts Estimated, Baseline Demand Forecast		
Category	**2015**	**2025**
Incremental variable operating costs incurred (billion)	$3.06	$5.82

Results for Low Demand Forecast

Figure 3-40 reports losses and costs to passengers in 2015 and 2025 due to NAS capacity shortfalls under the low alternative demand forecast. These costs range from $3.7 billion in 2015 to $12.7 billion in 2025. For 2015, the area of largest impact is the $1.9 billion cost to passengers from time lost to increased delay, while in 2025 the largest impact is again from losses of consumer surplus in the domestic air transportation market, which total $8.0 billion.

Figure 3-40. Summary of Passenger Impacts, Low Demand Forecast		
Category	**2015**	**2025**
Loss of consumer surplus in the domestic air travel market (billion)	$1.74	$8.04
Loss of consumer surplus in the international air travel market (billion)	$.01	$0.18
Value of GA passenger miles lost (billion)	$0.03	$0.10
Cost of incremental passenger delay experienced (billion)	$1.91	$4.42
Total (billion)	**$3.69**	**$12.7**

Even with a lower level of forecast demand, airlines face operating cost increases due to delays. For the lower level of demand for RPMs, these additional costs to airlines are reported in Figure 3-41. They range from $2.0 billion in 2015 to $4.7 billion in 2025.

Figure 3-41. Summary of Airline Impacts Estimated, Low Demand Forecast		
Category	**2015**	**2025**
Incremental variable operating costs incurred (billion)	$2.00	$4.66

Results for High Demand Forecast

Figure 3-42 reports losses and costs to passengers in 2015 and 2025 due to the NAS capacity shortfall under the high alternative demand forecast. These costs range from $8.4 billion in 2015 to $26.2 billion in 2025. The area of largest impact is the loss from consumer surplus in the domestic air transportation market.

Figure 3-42. Summary of Passenger Results, High Demand Forecast		
Category	**2015**	**2025**
Loss of consumer surplus in the domestic air travel market (billion)	$4.78	$19.40
Loss of consumer surplus in the international air travel market (billion)	$0.28	$0.95
Value of GA passenger miles lost (billion)	$0.09	$0.27
Cost of incremental passenger delay experienced (billion)	$3.29	$5.58
Total (billion)	**$8.44**	**$26.2**

With the higher demand forecast, airlines face even greater operating cost increases due to delays. For the higher level of demand for RPMs, these additional costs to airlines are reported in Figure 3-43. These range from $3.5 billion in 2015 to $5.9 billion in 2025. The relatively small difference in aircraft and passenger delay costs for the baseline and high demand forecasts implies that the system is reaching saturation when faced with baseline levels of activity growth.

Figure 3-43. Summary of Airline Impacts Estimated, High Demand Forecast		
Category	**2015**	**2025**
Incremental variable operating costs incurred (billion)	$3.46	$5.88

Separation of Passenger and Airline Impacts

For the three forecasts of demand for domestic RPMs used in this analysis, the impacts of capacity shortfalls on passengers have been reported separately from those on airlines. This is because the full range of impacts on airlines is complex and uncertain—impacts may result in cost increases passed on to some extent to passengers, changes in airline service quality, or other forms. In important ways, the approach used in this analysis—combining capacity constraints and market clearing prices to model the impact of capacity shortfalls as increases in average yields—simplifies from these uncertainties and complexities. Reporting separate impacts for the two sides of the air transport market helps to keep these complexities transparent.

A second reason to report the two types of impacts separately is the natural relationship between impacts that increase costs to service providers and impacts on passengers that arise from higher average fares. To the extent that the higher average fares faced by passengers reflect higher unit costs experienced by airlines in a more congested operating environment, the loss of consumer surplus by passengers is a sufficient measure of overall impacts.

In this context, it is important to note that if capacity shortfalls, whether they are due to inadequate public investment funding and planning or to some other cause, give airlines or other system participants new market power due to the scarcity created by the shortfalls, some of the surplus lost by passengers to higher average fares could be regarded as merely a transfer of social surplus from consumers to producers or their suppliers. Such a characterization acknowledges that passengers may have "lost" (relative to the consumer surplus that would have been theirs had capacity-enhancing investments been undertaken in the prior decade), and treats the increase in producer surplus as a compensating societal gain. In such a framework, a gain in the form of lower average fares is received by passengers in the unconstrained world, while in the capacity constrained world the gain is received by firms or other organizations that are able to accrue excess returns due to scarcity.

However, if the resource costs of the various factors of production at airlines, airports, and air traffic control are higher in the constrained world, then the difference in market clearing average yields for the constrained and unconstrained futures may reflect cost differences and not simply windfall gains received by producers due to the scarcity of capacity.

This study was not intended to account for all cost increases or scarcity returns that could occur in the production of air transport services, including impacts on airports, air traffic management, airlines, and other pieces of the system. In addition, the analysis relied on a market clearing model that unavoidably simplifies many complex differences that would come to exist between a commercial air transportation world that developed over several years of recurring system-wide capacity shortfalls and a commercial air transportation world that developed in an environment of more readily available capacity. Consequently, we have elected to use impacts on passengers, including differences in consumer surplus received in the constrained and unconstrained capacity settings, as the principal figure of merit for assessing the value of achieving an unconstrained air transportation environment compared to accepting a more capacity constrained future.[106]

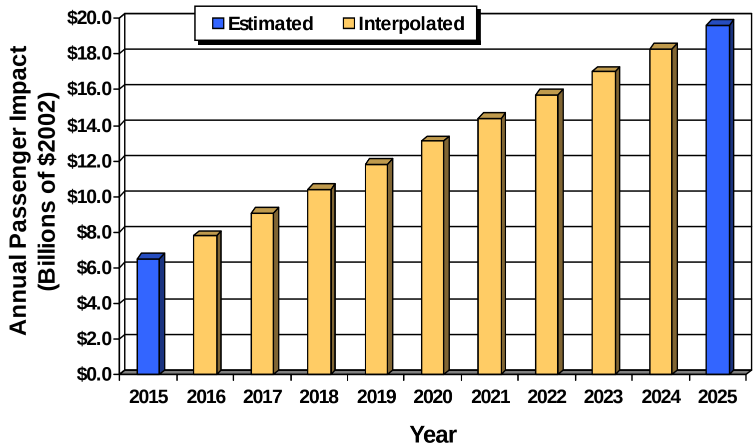
Aggregate Passenger Impacts

For each of the three forecast demand environments, effects of capacity constraints on passengers have been estimated for 2015 and 2025. These estimates are reported above in Figures 3-38, 3-40

[106] A recent study released by the National Research Council also measures the impact of NAS capacity shortfalls in terms of lost consumer surplus. Aeronautics and Space Engineering Board, *Securing the Future of U.S. Air Transportation: A System in Peril (September 2003)*

and 3-42. Of course, capacity constraints will not have consequence for passengers only in those years. There will be effects in each year between 2015 and 2025. Since forecast demand for domestic RPMs increases smoothly from year to year in each of the three forecasts, annual impacts on passengers from capacity constraints can be interpolated for each year between 2015 and 2025, using the impacts estimated for the two endpoints. Figure 3-44 provides a graphic depiction of the results of this interpolation process.

Figure 3-44. Annual Passenger Impacts, 2015 – 2025, Baseline Demand Forecast (Billions of Constant 2002 Dollars)



Once this interpolation has been made, the aggregate impact from 2015 to 2025 equals the sum of the 11 annual impacts. The aggregate impact for each of the three demand forecasts is reported in Figure 3-45. As can be seen, the baseline aggregate impact of the shortfall is $143.6 billion. For the low demand forecast, the aggregate impact reaches $91.6 billion, while it rises to $229.4 billion under the high demand forecast. Each of these values is in constant, undiscounted year 2002 dollars.

Figure 3-45. Aggregate Passenger Impacts, 2015 – 2025 (Billions of Constant 2002 Dollars)

Demand Forecast	Impact 2015 – 2025
Baseline	$143.6
High-end	$229.4
Low-end alternative	$91.6

Chapter 4. Other Alternative Futures

Attempting to predict the future in any aspect of life is an extremely complex undertaking, requiring a mixture of data, analysis, and expertise, as well as a liberal dose of luck. “Chapter 3. Futures and Forecasts” describes a conservative approach undertaken by the SEDF study team in developing a baseline demand forecast for future passenger air transportation in 2015 and 2025. Higher and lower alternatives were derived through a statistical simulation (Monte Carlo) process that used historical statistical relationships and the baseline forecast model to develop reasonable variations from the baseline forecast. Both the original baseline forecast and the alternatives were derived from well-accepted assumptions about the factors that contribute to passenger demand, particularly economic growth and future airfares, and their interrelationships. Therefore, they reflect a common set of basic inputs and relationships between these inputs.

However, the future air transportation system may not correspond closely to that implied by the inputs chosen for the forecasts in the SEDF study. A number of other qualitative factors can also affect society’s demand for air transportation services. Some of these factors are captured directly in the variables used in the demand forecast modeling process—in particular those that influence overall economic growth or that influence airline costs which in turn influence airline yields—while others may be have a more indirect impact on demand. Although they may be more challenging to model, changes in these indirect factors can result in changes in future demand levels. Among the more salient of these indirect variables are the impacts of environmental concerns, safety and security issues, future technological innovations, new air transportation systems and equipment, and new operational concepts and practices. To the extent that some of these indirect variables represent challenges or improvements that affect the economy as a whole, some of their effects on air transportation demand may be already captured through the quantitative modeling of changes in GDP growth rates and in annual changes in real yields.

The following discussion describes how many plausible futures could occur, depending on the outcome and impact of these indirect variables. Understanding these factors and the impact they could have allows a broader assessment of the future of the U.S. air transportation system. It reveals areas of particular importance in the future development of air transportation services, and identifies key components of the public policy issues that will influence the future course of the air transportation system’s growth.

BACKGROUND

Factors that have a primarily positive or stimulating impact on air transportation demand are termed “enablers” because they help or “enable” growth of the air transportation system. In contrast, factors that can have a primarily negative or retarding impact on growth are termed “constraints” because they constrain the growth of the air transportation system. The SEDF team developed a list of such enablers and constraints by drawing heavily from the following previous scenario-based planning studies:

- NASA: National Research Council, Aeronautics, and Space Engineering Board (ASEB). Maintaining U.S. Leadership in Aeronautics: Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise. Washington DC: National Academy Press, 1997. (5 scenarios for 2025)
- U.S. AIR FORCE: Col. J. Engelbrecht, Lt. Col. R. Bivins, Maj. P. Condray, Maj. M. Fecteau, Maj. J. Geis, Maj. K. Smith. Alternate Futures for 2025: Security Planning to Avoid Surprises. A research paper presented to Air Force 2025. April 1996. At http://www.au.af.mil/au/2025/monographs/A-F/a-f.htm. (5 scenarios for 2025).
- THE MILLENNIUM PROJECT of American Council for the United Nations University. 1998 State of the Future: Issues and Opportunities. At http://www.acunu.org (4 scenarios for 2052)
- U.S. DOT: U.S. Department of Transportation. ONE DOT Scenario Strategy Workshop. April 1999. At http://stratplan.dot.gov/StratPlan/PlanProcess/Future.cfm (4 scenarios for 2028)
- CIA: Central Intelligence Agency. Global Trends 2015: A Dialogue about the Future with Nongovernmental Experts. NIC 2000-02, December 2000. At http://www.odci.gov/cia/publications/globaltrends2015/index.html (baseline + 4 scenarios for 2015)

Additional information on these and the other scenario exercises consulted for this study can be found in Appendix C to this report.

These previous scenario-based analyses each developed several alternatives for how the future could unfold. These alternatives ranged from relatively unchanged projections of current trends to both highly optimistic and highly pessimistic views of what could occur. When these positive and negative scenarios were compared with each other, there were a number of similarities among them.

The positive, or high growth, scenarios shared several characteristics, many of which reinforce each other as they unfold. These characteristics include:

- Sustained worldwide economic growth at a higher than predicted level (i.e., economic growth of more than 3.1% per year globally), especially in the poorer nations
- Free international trade and financial systems with open markets and readily transferable investment capital
- Reductions in warfare, civil conflict, and international terrorism
- Adequate, low-polluting and affordable energy sources
- Overall reduction in fossil fuel emissions, resulting in declining levels of pollution and global warming
- Rapid expansion of global information networks, including telephone systems and the Internet
- New technological advances that benefit the global economy and quality of life

The negative (or low growth) scenarios also shared a number of mutually reinforcing characteristics:

- Lower than anticipated economic growth rates, with poorer regions of the world sinking even deeper into poverty

- Breakdowns in international trade and investment systems, often accompanied by competitive, inwardly focused regional trading blocs

- Continued global conflicts, civil disorder and terrorist incidents

- Scarce, costly and highly polluting energy sources

- Continued increases in pollution and greenhouse gases, often leading to catastrophic natural calamities due to global warming

- Increase in inequities, with richer nations monopolizing the benefits of improved technologies such as the Internet and air transportation to themselves at the expense of the majority of the world's population

These five scenario analysis studies, as well as several additional scenario exercises, were assessed for common themes and factors that could affect economic growth and quality of life in both positive and negative directions, with special attention to those that could impact air transportation demand and service levels. A subset of variables that can be seen as either "enablers" or "constraints" to air transportation demand were developed and then aggregated into three different categories, depending on the specific aspect of the demand forecast that they most heavily influenced. These three categories are:

- Those that primarily affect economic and population growth

- Those that primarily impact the cost or relative cost of air travel (yield)

- Those that primarily impact other factors, primarily the propensity of individuals to choose air transportation when traveling

The potential impacts of these variables on future air transportation demand can be assigned three value ranges: one that corresponds to the baseline SEDF, one that suggests lower growth and one that suggests higher growth. Depending on the values and emphasis assigned to each of these variables, it is possible to construct a large number of differing forecasts for what the demand for air transportation services could be in 2015 and 2025, which are the two points assessed for the National Plan. These categories, and the variables included in them, are summarized in Figure 4-1.

SEDF ENABLERS AND CONSTRAINTS

GDP/POPULATION VARIABLES

A key determinant of air transportation demand is the size and affluence of the population, expressed in terms of GDP and population growth rates. Higher growth rates lead to higher demand levels, while lower or negative growth rates accompany lower demand levels. Among the variables that can impact population and economic growth are the relative presence (or absence) of the following:

- Mass population movements, such as refugee flows and disruptive migrations of large numbers of people due to economic stress or other factors

- Open international trade and financial systems

- Conflict, civil strife, and/or international terrorism

- Strong global communications and transportation networks, including widespread access to international airports and the Internet

- Environmental threats such as global warming or rising pollution levels

Figure 4-1. SEDF Enablers and Constraints for Other Alternative Futures

Item	Low Growth Futures	Baseline Future	High Growth Futures
1. Primary impact on GDP/population			
a. Level of disruptive mass population movements (migration, refugees)	High	Normal	Low
b. Level of global economic/financial integration	Low	Normal	High
c. Level of open international trade	Low	Normal	High
d. Extent of Global Information Network integration (telephone, Internet, TV, radio, etc.)	Low	Normal	High
e. Extent of global warming	High	Normal	Low
f. Impact of new successful "Green" technologies	Low	Normal	High
2. Primary impact on yield w/ taxes			
a. Airline labor productivity	Low	Normal	High
b. Infrastructure productivity (airports and air traffic control)	Low	Normal	High
c. Aviation fuel prices	High	Normal	Low
d. Network carriers adapt business models to changing industry conditions	Adapt poorly	Normal	Adapt very well
e. Cost savings from new and/or more efficient aircraft models introduced	Low	Normal	Moderate/high
f. Level of air transportation taxes and fees	High	Normal	Low
g. Cost of capital for airports and airlines	High	Normal	Low
h. Level of competition	Low	Normal	High
i. Cost of environmental mitigation	High	Normal	Low
3. Primary impact on other factors (propensity to travel, etc.)			
a. Perceptions about air transportation safety	More concern	Normal	Less concern
b. Perception about security of air transportation (terrorism, etc.)	Less secure	Normal	More secure
c. Concern over environmental impact of air transportation (global warming, emissions, noise, etc.)	High	Normal	Low
d. Attractiveness of telecommunications as an alternative to air travel	High	Normal	Low
e. Attractiveness of other transportation modes (rail, highway, etc.) as an option to aviation	High	Normal	Low
f. Lost time and inconvenience in air travel due to delays, surface congestion, security inspection delays, passenger/baggage processing delays, etc.	High	Normal	Low
g. Perception of risk of foreign destinations (terrorism, war, health, etc.)	High	Normal	Low
h. New aircraft models (e.g., SATS, RIA, superjumbo, etc.) and other technological advances that enhance capacity and/or productivity	Few	Normal	Many

YIELD VARIABLES

A second major determinant of air transportation demand is the cost of a trip to the traveler in the form of ticket fares, taxes and surcharges. This factor is usually expressed in terms of "yield," or revenue per passenger seat mile. Higher yields mean more expensive travel, and thus a lower level of total demand. In contrast, lower yields usually correspond with higher levels of demand. Historically, the "real yield" (adjusted to remove the effects of price inflation on air fares) for airline passenger travel has been declining at an average rate of about 2% each year for the past thirty years. The most important determinant of yield is the cost to provide air transportation services, which in turn is composed of a number of key factors. These include:

- Personnel costs—e.g., salaries, benefits, etc.—and the level of labor productivity

- Aviation fuel prices

- The efficiency and responsiveness of the business models adopted by service providers (airlines and airports)

- Cost savings due to new equipment and technologies

- Taxes, fees and surcharges imposed on air travelers
- The cost of capital for airlines, airports and other suppliers to the industry
- The level of competition and its impact on prices

PROPENSITY TO TRAVEL AND OTHER VARIABLES

A third possible determinant of the level of air transportation demand is the collective impact of factors not directly related to GDP, population, or yield. Many of these can be categorized as influences upon an individual's decision on whether to travel and by what mode that reflect considerations other than the price of travel. These factors include:

- The perceived safety of the trip
- The perceived security of the trip
- The potential negative environmental consequences of the trip (increased noise, pollution, etc.)
- The attractiveness of alternatives to flying, such as driving, intercity rail service or teleconferencing
- The inconveniences associated with flying, such as delays at airports due to traffic or gate congestion, parking difficulties, security inspections, baggage retrieval, etc.
- New aircraft models and air transportation systems, equipment, and operational practices that improve the air transportation system and its performance

USE OF ENABLERS AND CONSTRAINTS IN FORECASTING DEMAND

For purposes of this report, the baseline forecast represents a future in which the many variables that contribute to the demand for air transportation services reflect current conditions and exhibit trends that continue into the future without significant change. This is represented by the "Baseline Future" column in Figure 4-1.

Lower growth futures may come about if a significant number of these variables would change in ways that inhibit (or constrain) the growth of air transportation demand. These conditions are identified in the Low Growth Future column of Figure 4-1. Higher growth futures, in contrast, reflect circumstances in which a significant number of these variables would develop over time in a manner that would stimulate—or enable—the demand for air transportation services at a higher level than that of the baseline forecast. These conditions are identified in the High Growth Future column of Figure 4-1. A nearly infinite number of possible future demand levels can be developed by varying the relative value and weight of the enablers and constraints under different circumstances.

The first two categories of variables—those that impact GDP/population and yield—are traditionally the most important direct inputs into air transportation forecast models because of their strong historic relationship with air transportation demand. Future values for these factors were kept within a relatively narrow range that reasonably corresponded to their historical values in recent years and their relative significance to demand. However, it is not certain that the impact of these factors on demand will remain unchanged into the future; that these relationships would remain stable is a reasonable assumption that was made in order to develop credible baseline demand forecasts.

For example, it was assumed that no major global crisis would occur that would seriously disrupt international relations, economic growth, or the environment. Likewise, it was also assumed that no major breakthrough would occur in diplomacy, productivity or technology that would contribute to even higher levels of political stability, economic growth or a reduction in environmental concerns than a projection of current trends would suggest. Significant deviations in either direction from these assumptions could happen, which would have a measurable impact on the demand projections.

The third category of variables is traditionally not directly incorporated into future demand forecasting exercises either because quantitative data on them is scarce or difficult to obtain, or because quantitative analysis of these factors is itself problematic. For example, it is difficult to determine a quantitative means of assessing how many passengers are deterred from flying primarily because of their personal concerns over air transportation security or the delays and inconvenience of the more stringent security screening procedures that have been imposed in recent years. Experience also suggests that many airports have been unable to expand their flight operations due to pronounced opposition from their local communities to the adverse environmental and quality of life impacts that would occur—particularly increases in noise, pollution, and highway congestion.

Many other possible future developments and trends may have a significant impact on air transportation demand forecasts and/or the overall capacity or efficiency of the air transportation system. New aircraft models with new or improved characteristics could handle more passengers at a lower total cost, or could divert significant numbers of passengers from large, crowded airports to smaller airports with unused capacity. Air carriers could adopt new or modified business models that could enable them to increase service while making a profit. New cost-effective air traffic management systems, equipment or concepts could accommodate higher levels of operations and passengers without leading to higher prices or longer delays. New security systems and procedures could shorten the time needed to screen passengers and baggage. New engines and fuels could lower the noise and emissions levels associated with aviation

These are only a few examples of ways in which the future of air transportation could look quite different from the present. Rather than ignore these important factors because they are not traditionally included or are difficult to incorporate into air travel demand forecasting, the SEDF team has chosen to acknowledge their existence and potential significance. In doing so, these factors become potential topics for additional research that could more accurately assess their impacts on the air transportation system and air travel demand and lead to a more in depth forecasting analysis.

Conclusions

U.S. economic prosperity and quality of life depend on an air transportation system that can accommodate future demand. Implementing the OEP will not be enough. Now is the time to begin designing the air transportation system of the future. Such an ambitious undertaking will require focused research and technology development and new public policy changes that systematically coordinate airport, aircraft, and air traffic control system technologies and procedures. The SEDF study quantifies the potential costs to the nation if capacity fails to keep pace with demand. As such, the study provides the foundation for additional studies that must consider both the benefits and the costs of transforming the system to meet 21st century needs.

TThe federal government must accept the leadership challenges posed by an aging air transportation system and the impact that continued population growth, increased globalization, and new security needs will have on demand, which will soon more than double peak levels experienced in 2000. Full implementation of the FAA OEP by 2015 will slow inevitable increases in congestion and delay, but such improvements will not prevent it or adequately contain it. Air traffic initiatives and runway expansion plans alone are not enough. The only way to prepare the nation to meet 21st century air transportation needs is to transform the entire system.

Such a transformation must engage the public and private sectors in a collaborative partnership that draws on unique strengths for a common purpose. Such a partnership must begin with government leadership. Secretary Mineta demonstrated such leadership recently when he asked the President to launch the *Next Generation Air Transportation Initiative*. The ATS-JPO supports the Secretary's effort with the *National Plan to Transform Air Transportation*, a two-volume government-industry business plan that will establish goals, priorities, and long-term strategies to guide decisions in the federal government, air transportation industry, and international community. [107, 108]

A key purpose of the national plan will be to "make it clear that the nation needs to create a flexible system that is prepared to enable a range of potential futures…" The plan will also demonstrate "why business as usual is insufficient." [109] The SEDF study described in this report provides the foundation for such a case by quantifying the cost to the nation of business-as-usual—i.e., that despite full implementation of the OEP by 2015, demand for air transportation services will soon outstrip NAS capacity and will culminate in a cumulative economic cost to the nation of hundreds of billions of dollars by 2025.

Future ATS-JPO studies must consider both the benefits and the costs of system transformation as additional strategies and information emerge from a national plan to transform the U.S. air transportation system. Key elements of the plan currently in development include:

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[107] "MEMORANDUM OF UNDERSTANDING/AGREEMENT BETWEEN THE DEPARTMENT OF TRANSPORTATION (DOT), DEPARTMENT OF COMMERCE (DOC), DEPARTMENT OF DEFENSE (DOD), DEPARTMENT OF HOMELAND SECURITY (DHS), AND NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA), for the Air Transportation System Joint Planning and Development Office (ATS-JPDO)," (draft, undated, unsigned). The ATS-JPD "will satisfy the U.S. Government's fundamental civil and national security requirements for creating and carrying out an integrated plan for a Next Generation Air Transportation System (NGATS) by recommending research and development on that system; creating an ATS Integrated Transition Plan (ITP) for the implementation of that system; coordinating aviation and aeronautics research programs …; coordinating goals and priorities and…research activities within the Federal Government with United States aviation and aeronautical firms; coordinating the development of new technologies …facilitating the transfer of technology ..to other Federal agencies…and the private sector; reviewing activities related to noise, emissions, fuel consumption, and safety conducted by Federal agencies…"

[108] ATS- JPO Working Draft Outline for a National Plan to Transform Air Transportation.

[109] ibid

- **The Need for Transformation**: a compelling case that "makes(s) it clear that the community needs to create a flexible system that is prepared to enable a range of potential futures and (demonstrates) why business as usual is insufficient." The SEDF study detailed in this report provides a foundation for such a case.

- **Air Transportation System Goals and Objectives**: performance requirements that will characterize a future air transportation system capable of accommodating demand

- **Transition Barriers** : economic, policy, technical, and organizational obstacles that could impede development and implementation of a system capable of meeting demand

- **Transformation Strategies**: strategic approaches for overcoming obstacles in order to meet goals and objectives[110]

A CASE FOR GOVERNMENT INVESTMENT

Government investment in the air transportation system will produce tangible benefits. A recent review of the literature on the economic benefits of public investment in transportation infrastructure concluded that "(p)ublic sector investments in transportation infrastructure result in long-term economic benefits on the production or supply side—e.g., increased output, increased productivity, reduced costs of production or increased income."[111]

The FAA's ability to support long-term systems analysis and requirements definition is limited, however, because so much effort is expended to solve more immediate problems and keep the air transportation system operating."[112] NASA and the FAA must, therefore, establish requirements for NASA research "that are relevant to the air traffic management systems that the FAA is likely to procure in the future."

Much of today's air transportation system modernization is funded through the FAA's Airport and Airway Trust Fund, which provides for development and acquisition of air traffic control technology and capacity improvements at airports. Other airport costs are recovered from the users of airport services including commercial aviation, private aviation, passengers, and shippers.

The federal government has a responsibility to invest in three key areas: coordinating change among all elements of the air transportation system, conducting research and technology development, and changing the infrastructure.

Coordinating investment in airports, air traffic management, and aircraft. Transformation of the air transportation system will require investment in research and technology for application to airports, the air traffic management system, and aircraft. Full benefits will not be realized without full participation from all parties. Many government bodies also have a stake in the future air transportation system. Coordinating issues and activities among multiple government agencies and departments requires government leadership.

Research and technology. Historically, NASA and FAA have conducted research to improve air traffic management, while the FAA has funded airport research. NASA also funds research in aeronautics technologies. Transformation of the system to meet 21st century needs will require even greater government participation. Today, under the leadership of the Secretary of Transportation, the

[110] These are working titles of chapters currently planned for the national plan.

[111] Bhatta and Drennan, op cit., p. 295.

[112] Letter Report to the Honorable John H. Marberger, III, August 14, 2002, Attachment A, p. 5, prepared by the Aeronautics and Space Engineering Board Committee on Aeronautics Research and Technology for Vision 2050.

DHS/TSA, DOC, and DOD are already participating in the ATS-JPO, together with NASA and the FAA.

Several factors inhibit or prevent private sector investment in the kind of research and technology development that will be required to transform the nation's air transportation system. The absence of private markets for research and technology to mitigate aircraft noise, emissions, or congestion, or to increase NAS capacity (which is not priced at most airports in the United States[113]) is one factor. Long lead times (which can take ten years or more) to advance air traffic control technologies from fundamental research to products ready to deploy is another. The high cost of technology validation to the reduce risk of failure also inhibits private sector investment in 21st century air traffic control system research.

Thus, while it ultimately delivers most air traffic management products, the private sector finds it difficult to capture a sufficient return on investment from research and thus has little incentive to conduct basic and applied research or fund technology validation. Government investment is therefore essential.

Infrastructure. Because the federal government owns, operates, or provides the nation's airport and air traffic control infrastructure, it has a unique responsibility to invest in research and technology development to transform them to meet 21st century needs.

- The FAA operates the air traffic control system, and governments or government authorities operate most U.S. airports.
- The government operates air traffic control as a monopoly, and many airports enjoy locational monopolies on the provision of service. Public bodies generally operate on a cost-recovery basis through fees-for-service or indirect air transportation taxes paid by passengers and shippers.
- Air transportation infrastructure is not explicitly priced, so the private sector is unlikely to produce an amount sufficient to support public need.

Airlines may in fact find incentives to restrict capacity if such a shortfall would allow them to charge higher fares. In a recent report of regulatory issues, the OMB noted that:

> "Firms exercise market power when they reduce output below what would be offered in a competitive industry in order to obtain higher prices. They may exercise market power collectively or unilaterally. Government action can be a source of market power, such as when regulatory actions exclude low-cost imports. Generally, regulations that increase market power for selected entities should be avoided." [114]

PUBLIC-PRIVATE PARTNERSHIPS

Government must encourage industry, labor, and academic institutions to work together to support transformation of the air transportation system and reward them for collaborative efforts in research, product development, and engineering, and in delivering products and services that harness their unique strengths and skills. For example, tax incentives can encourage industry and academia to

[113] The buy-sell provisions for slots awarded under the High Density Rule allowed a secondary market to function at four U.S. airports.

[114] OMB, Office of Information and Regulatory Analysis. Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local and Tribal Entities, pp. 121-122.

work together to sponsor advanced research, make capital investment in universities, and provide trained staff and products. [115]

Public and private sectors also need a new, more flexible and integrated product development process that stimulates new ideas and turns them into products and services faster.[116] Essential characteristics include:

- Coordinated national goals
- Aggressive use of information technologies
- Incentives for public-private partnership
- Acquisition process that integrates science and technology into the product development process

FUNDING ISSUES

A key question surrounding the cost of transformation concerns how to pay for it. The answer depends in part on fiscal requirements, whether funding will be available from the Airport and Airway Trust Fund, and if so, whether the amount will be sufficient. If funds are unavailable or insufficient, users or others may be required to contribute. Such a need for additional funding could affect current assumptions about the future price of flying, which could in turn affect the SEDF study results.

FUTURE STUDIES

Areas in need of future analysis include the cost of transformation relative to the cost of business as usual—a full cost-benefit analysis of transformation. Such a study would build upon the work reported here. Additional studies should also examine the economic impact of air cargo and regional issues associated with the U.S. air transportation system.

SUMMARY

The federal government has an opportunity and a responsibility to make a dramatic and material difference to the nation's continued economic prosperity and quality of life through leadership and investment in a new initiative to transform the U.S. air transportation system. Many different proposals and approaches to transformation will emerge, and each will have its champions. No single solution will win out. Rather, transformation will require a portfolio of change, innovation, and improvement. Each element will provide some new or enhanced capability aimed at increasing capacity. Some may even increase demand.

Transformation will follow from technological innovation, new business models and best practices, and new service categories. Some improvements will result from increases in the NAS capacity. Others will derive from reductions in noise, pollution, and other factors associated with air travel. Still others will result from increased safety and security. One thing is certain. The next century of powered flight will prove as surprising and eventful as the first 100 years.

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[115] *Final Report on the Future of the United States Aerospace Industry*, pg 9-10.
[116] Ibid.

APPENDICES

APPENDIX A. Bibliography

Aerospace Facts and Figures, 2002-2003. Washington, DC: Aerospace Industries Association of America, 2002.

Air Transport Association. *Airlines in Crisis – The Perfect Economic Storm*. Washington, DC, March 11, 2003. http://www.airlines.org/public/industry/display1.asp?nid=1026

Airbus Industrie. *Global Market Forecast, 2000-2019*. Blagnac Cedex, FR, 2000.

_____. *Global Market Forecast, 2001-2020*. Blagnac Cedex, FR, 2001.

Airports Council International – North America. *The Economic Impact of U.S. Airports*. Washington, DC, 2002.

Alperovich, Gershon, and Yaffa Machnes. "The Role of Wealth in the Demand for International Air Travel," *Journal of Transport Economics and Policy* 28(2): 163-173, 1994.

BAE Systems. *Updating and Development of Economic and Fares Data Regarding the European Air Travel Industry. 2000 Annual Report*. (Prepared for the EEC, Directorate General Energy and Transport)
http://europa.eu.int/comm/transport/themes/air/english/library/annual_report_2001_v2.pdf

Berechman, J. "Transport Investment and Economic Development: Is There a Link?" IN *Transport and Economic Development; Report of the Hundred and Ninth Round Table on Transport Economics, Paris, March, 2001*. Paris: OECD, 2002 , p. 103-138. (European Conference of Ministers of Transport, Round Table no. 119)

Bhatta, Saurav Dev and Matthew P. Drennan. "The Economic Benefits of Public Investment in Transportation; a Review of Recent Literature," *Journal of Planning Education and Research 22:288-296, 2003.*

Boeing Commercial Airplanes. *Current Market Outlook 2001*. Seattle, WA, 2001.

_____. *Current Market Outlook 2003*. Seattle, WA, 2003

Bureau of Economic Analysis. "Background Information on Tourism Satellite Accounts," Washington, DC, June 12, 2003. http://www.bea.doc.gov/bea/newsrel/tourbackground.htm

_____. "Regional Accounts, RIMS II, Regional Multipliers from the Regional Input-Output Modeling System (RIMS II): A Brief Description," Washington, DC, 1997.
http://www.bea.gov/bea/regional/rims/brfdesc.htm

_____. "Sales of U.S. Tourism Industries: Fourth Quarter 2002," Washington, DC, March 17, 2003. (Press Release)

_____. "U.S. International Transactions: Fourth Quarter and Year 2002," Washington, DC, March 14, 2003. (Press Release)

Bureau of Labor Statistics. "How BLS Measures Price Change for Airline Fares in the Consumer Price Index," Washington, DC, October 16, 2001. http://www.bls.gov/cpi/cpifacaf.htm

Bureau of Transportation Statistics. *The 1995 American Travel Survey*, Microdata CD-ROM, BTS-CD-22, Washington, DC, August 1999.

Bureau of Transportation Statistics. Office of Airline Information. *Number of Employees, Certificated Carriers, Year End Data 1997.* http://www.bts.gov/oai/employees/1997emp.html

Bureau of Transportation Statistics and Census Bureau. *1997 Economic Census, Transportation, 1997 Commodity Flow Survey*. Washington, DC: U.S. Department of Transportation, and U.S. Department of Commerce, 2000.

Census Bureau. *1997 Economic Census – Transportation and Warehousing*. 2001. http://www.census.gov/epcd/ec97/us/US000_48.HTM

Cohen, Jeffrey P. and Cletus C. Coughlin. "Congestion at Airports: the Economics of Airport Expansions," *Federal Reserve Bank of St. Louis Review* 85(3): 9-25, 2003.

Commission on the Future of the United States Aerospace Industry. *Final Report*. Washington, DC, November 2002. http://www.ita.doc.gov/aerospace/aerospacesommission

Congress. Office of Management and Budget. ""Draft 2003 Report to Congress on the Costs and Benefits of Federal Regulations," Washington, DC, 2003. http://www.whitehouse.gov/omb/fedreg/2003draft_cost-benefit_rpt.pdf

Crouch, Geoffrey I. "Demand Elasticities for Short-Haul Versus Long- Haul Tourism," *Journal of Travel Research* 33(2): 2-7, 1994.

Department of Transportation. *Strategic Plan, 2000-2005*. Washington, DC, July 2000.

Douglas, John W. "Implementing the Recommendations of the Commission on the Future of the U.S. Aerospace Industry," Statement before the House Science Committee, March 12, 2003. http://www.house.gov/science/hearings/full03/mar12/douglass.htm

DRI-WEFA, Inc., and The Campbell-Hill Aviation Group, Inc., *The National Economic Impact of Civil Aviation*, July 2002. http://www.globalinsight.com/Highlight/HighlightDetail174.htm

"Economic Effects of the September 11 Terrorist Attacks: A Survey of Current Studies and an Overview of the Implications for Transportation," Cambridge, MA: Volpe National Transportation Systems Center, 2003?

Executive Office of the President. Office of Management and Budget. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Washington, DC, 1995. (OMB Circular A-94)

Fang, Bingsong, Xiaoli Han, Sumiye Okubo and Ann M. Lawson. "Transportation Satellite Accounts for 1996," *Survey of Current Business* 80(5): 14-22, May 2000.

Federal Aviation Administration. *Airport Capacity Benchmark Report 2001*. Washington, DC, 2001. http://www.faa.gov/events/benchmarks

_____. *Deregulation and its Effect on FAA Methods for Forecasting Commercial Air Carrier Demand*. Washington, DC, 1989.

_____. *FAA Aerospace Forecasts--Fiscal Years 2000-2011*. Washington, DC, 2002. (FAA-APO-00-1)

_____. *FAA Aerospace Forecasts—Fiscal Years 2002–2013*. Washington, D.C., March 2002. (FAA-APO-02-1)

_____. *FAA Aerospace Forecasts—Fiscal Years 2003-2014.* Washington, DC, March 2003. (FAA-APO-03-1)

_____. *FAA Airport Benefit-Cost Analysis Guidance*, Washington, DC, December 15, 1999.

_____. *Guide for Airport Financial Reports Filed by Airport Sponsors*, Washington, DC, January 15, 2003. (Advisory Circular 150/5100-19B, Change 2)

_____. *National Plan of Integrated Airport Systems (NPIAS), 2001-2005*. Washington, DC, 2002. http://www2.faa.gov/arp/planning/npias/index.cfm?ARPnav=npias

_____. *Terminal Area Forecast Summary, Fiscal Years 2000-2015*. Washington, DC, December 2000. (FAA-APO-00-7)

_____. *Terminal Area Forecast Summary, Fiscal Years 2001-2016*. Washington, DC, December 2001. (FAA-APO-01-7)

Fogelman, Ronald R. "Aerospace Research and Technology for Vision 2050 – Phase 1 Letter Report; Assessing Future Goals and Visions for National Civil Aviation." Washington, DC: National Academies, August 14, 2002. http://www.national-academies.org/aseb

Ghobrial, A. "A Model to Estimate the Demand Between U.S. and Foreign Gateways*," International Journal of Transport Economics* 20(3): 271– 283, 1993.

Gillen, David, William G. Morrison and Christopher Steward. "Air Travel Demand Elasticities: Concepts, Issues and Measurement," Waterloo, ON: Wilfred Laurier University, November 2002.

GRA, Inc. *Alternate Airports Study*. Jenkintown, PA, April 15, 2003.(Prepared for U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy.)

_____. *Economic Analysis of Aeronautical Research and Technology: A Survey*. Jenkintown, PA, 1999. (Prepared for Office of Aerospace Technology, NASA under subcontract to SAIC)

Grubb, Howard and Alexina Mason. "Long Lead-time Forecasting of UK Air Passengers by Holt-Winters Methods with Damped Trend," *International Journal of Forecasting* 17:71-82, 2001.

Han, Xiaoli and Bingsong Fang. "Measuring Transportation in the U.S. Economy," *Journal of Transportation and Statistics 1(1): 94-102,* January 1998.

Heimlich, John. "U.S. Airlines: Historical Trends," Washington, DC: Air Transport Association, May 27, 2003. http://www.airlines.org/public/industry/bin/Econ101.pdf

_____. "U.S. Airlines: The Road to Resuscitation," Washington, DC: Air Transport Association, June 30, 2003. http://www.airlines.org/public/industry/bin/Econ102.pdf

Hoffer, Stefan et al. *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*. Washington, DC: Federal Aviation Administration, June 1998. (FAA-APO-98-8) http://apo.faa.gov/apo3/tofc.htm

Hoppin, David F. "Air Cargo: Growth in a Period of Global Economic Uncertainty," Presentation to the 28th Annual FAA Aviation Forecast Conference, March 18, 2003, Washington, DC.

Howrey, E. Philip. "On the Choice of Forecasting Models for Air Travel," *Journal of Regional Science* 9(2): 215-224,1969.

International Air Transport Association. *The Economic Benefits of Air Transportation*. Geneva, SW, 2000. http://www.atag.org/files/EconomicBenefitsAirTransport.pdf

_____. *Freight Forecast, 1999-2003*. Montreal, PQ, 1999. 2 vols.

_____. *Passenger Forecast, 1998-2002*. Montreal, PQ, 1998.

International Civil Aviation Organization. *Outlook for Air Transport to the Year 2010*. Montreal, PQ, 2001. (Cir 281)

International Civil Aviation Organization. Committee on Aviation Environmental Protection. *Report of the Forecasting and Economic Support Group(FESG) to CAEP/4*. Montreal, April 1998.

International Civil Aviation Organization. The North Atlantic Traffic Forecasting Group, 33rd Meeting, 7 May-16 May, 2002. *North Atlantic Traffic Forecasts for the Years 2002-2007, 2010, 2015*. Paris, FR, 2002.

Jane's All the World's Aircraft. Coulsdon, United Kingdom: Jane's Information Group Limited, various editions.

Kaemmerle, Kenneth C. and George B. Dresser. *A Methodology for Estimating the Demand for Small Community Air Service*. College Station, TX: Texas Transportation Institute, 1988. (FA-86-SW-8954-3) (Available from NTIS)

Kass, David I. and Sumiye Okubo. "U.S. Travel and Tourism Satellite Accounts for 1996 and 1997," *Survey of Current Business* 80(7): 8-24, July 2000.

Klenow, Peter J. "Measuring Consumption Growth: The Impact of New and Better Products," *Federal Reserve Bank of Minneapolis Quarterly Review* 27(2): 10-23, Winter 2003. http://www.klenow.com/QRC.pdf

Kuhbach, Peter D. and Mark A. Planting. "Annual Input-Output Accounts of the U.S. Economy," *Survey of Current Business* 81(1): 9-43, January 2001.

Lawson, Ann M. "Benchmark Input-Output Accounts for the U.S. Economy, 1992," *Survey of Current Business* 77(11): 36-82, November 1997.

Long, Dou, David Lee, Jesse Johnson, and Peter Kostiuk. *A Small Aircraft Transportation System (SATS) Demand Model*. June 2001. (NASA/CR-2001-210874)

Long, Dou et al. *A Method for Evaluating Air Carrier Operational Strategies and Forecasting Air Traffic with Flight Delay*. McLean, VA: Logistics Management Institute, October 1999. (LMI report NS902S1)

_____. *Upgrading LMINET—A Queuing Network Model of the National Airspace System*. McLean, VA: Logistics Management Institute, February 2002.

Long, Wesley H. "The Economics of Air Travel Gravity Models," *Journal of Regional Science* 10(3): 353-363, 1970.

McCahill, Robert J. and Brian C. Moyer. "Gross Domestic Product by Industry for 1999-2001," *Survey of Current Business* 82(11): 23-41, November 2002.

Melville, J. A. "An Empirical Model of the Demand for International Air Travel for the Caribbean Region," *International Journal of Transport Economics* 25(3): 313-336, 1998.

Montalvo, Jose G. "A Methodological Proposal to Analyze the Economic Impact of Airports," *International Journal of Transport Economics* 25(2):181-203, 1998.

National Research Council. Steering Committee for a Workshop to Develop Long-Term Global Aeronautics Scenarios. *Maintaining U.S. Leadership in Aeronautics; Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise.* Washington, DC: National Academy Press, 1997.

Norris, Bahar and Richard Golaszewski. "Economic Development Impact of Airports: A Cross-Sectional Analysis of Consumer Surplus," IN *Transportation and Economic Development – 1990*. Washington, D.C.: Transportation Research Board, 1990, p. 82-88. (TRB Transportation Research Record no. 1274)

Oxford Economic Forecasting. *The Contribution of the Aviation Industry to the UK Economy. Final Report*. Oxford, November 1999. http://www.oef.co.uk/Free/pdfs/aviation.pdf

_____. *The Economic Contribution of Aviation to the UK: Part 2 – Assessment of Regional Impact*. Oxford, May 2002. http://www.oef.co.uk/Free/pdfs/FinalAviationReport(May02).pdf

Pitfield, D. E. "Predicting Air Transport Demand," *Environment and Planning A* 25: 459-466, 1993.

Rolls Royce. *The Outlook: 2001-2020*. Derby, GB, 2001. www.the-outlook.net

Snecma Moteurs. *Commercial Aircraft Market Forecast 2000-2019*. Moissy-Cramayel, FR, 2000.

Testa, William A. "Job Flight and the Airline Industry: The Economic Impact of Airports in Chicago and Other Metro Areas," Chicago: Federal Reserve Bank of Chicago, 1992. (Working Paper 1992/1)

Transportation Research Board. *Aviation Demand Forecasting; a Survey of Methodologies*. Washington, DC, 2002. (E-Circular E_C040)

Tucker, J. Robbins. "Economic Impact of Civil Aviation on the U.S. Economy – Update 2002 – Interim Results," Washington, DC: Federal Aviation Administration, July 9, 2002

Verbeke, A. and K. Debisschop. "A Note on the Use of Port Economic Impact Studies for the Evaluation of Large Scale Port Projects," *International Journal of Transport Economics* 23(3): 247-266, October 1996.

Vilain, Pierre. "Is Market Saturation in the Airline Industry Upon Us?" Paper Presented at the 77th Annual Meeting of the Transportation Research Board, Washington, DC, January 1998.

"Volpe Air Forecasting Model," Cambridge, MA: Volpe National Transportation Systems Center, 1994.

Weisbrod, Glen and Michael Grovak. "Comparing Approaches for Valuing Economic Development Benefits of Transportation Projects," Presented at the 77th Annual Meeting, Transportation Research Board, Washington, DC, January 1998.

Wilbur Smith Associates and Applied Management Solutions, Inc. *The Economic Impact of Civil Aviation on the U.S. Economy – 2000.* Columbia, SC, March 2000.

Wingrove, Earl R., III, Jing Hees, Justin Oberman, David Ballard and Richard Golaszewski. *Airline Scenarios for Transportation Demand and Economic Analysis.* McLean, VA: Logistics Management Institute, January 2003. (LMI report NS255S1)

Wingrove, Earl R. III; Jing Hees; and James A. Villani. *The Integrated Air Transportation System Evaluation Tool.* November 2002. (NASA/CR-2002-211961)

APPENDIX B. Key Assumptions

1. The SEDF aviation forecasting approach begins with national forecasts of passenger demand and aircraft operations. Operations were then distributed to airports and markets, from which estimates of the potential gap between future capacity and demand were derived.

2. The SEDF baseline forecast conforms to *FAA Aerospace Forecasts Fiscal Years 2003-2014* (FAA-APO-03-1, March 2003).
   a. The FAA forecast provides national estimates of air passengers, passenger miles, flights and available seat miles for US domestic and international travel by large jet aircraft and smaller regional/commuter aircraft.
   b. The SEDF baseline forecast were generated using the FAA's models and input data (projected growth in population and income; fuel prices, etc.).
   c. The SEDF baseline forecast is consistent with FAA projections of average yield, average aircraft sizes (number of seats), segment lengths, and load factors.
   d. The SEDF study team assumed that shares of flight operations at each of the major airports were consistent with FAA Terminal Area Forecast projections.
3. The SEDF baseline forecast implicitly assumes that network carrier costs were reduced sufficiently such that
   a. All or most network carriers will remain operational.
   b. Average real yield will continue its historic decline.
4. Two additional forecasts were developed showing higher and lower growth from the baseline. These alternatives were based on:
   a. Variations in economic growth
   b. Variations in airline yield changes
5. Baseline system capacity will include planned enhancements to air traffic control technology, increasing effective airport capacity.
   a. OEP in place by 2013
   b. No improvements beyond 2015
6. The existing route structure that provides a mixture of hub-and-spoke and point-to-point flight is assumed to continue into the future. Load factor, average aircraft size, and aircraft stage length were consistent with the FAA Long Range Forecast.

7. The SEDF baseline and alternative forecasts are unconstrained. These demand forecasts were compared to anticipated air traffic control and airport capacity to measure the shortfall.
8. The economic cost of air capacity shortfalls were derived from estimates of flights foregone, higher prices for air travel, and increased delay.
9. General aviation (GA) flights were included in the analysis. All-cargo flights were not included. The analysis does examine belly cargo impacts, but only qualitatively

APPENDIX C. Previous Scenario-Based Studies

The list of enablers and constraints developed for the Socio-Economic Demand Forecast study drew heavily from several previous futurist scenario exercises. The five specific scenario collections most relevant to the SEDF study are summarized below. These and other scenario collections consulted are listed at the end of this Appendix.

NASA

NASA: National Research Council, Aeronautics and Space Engineering Board (ASEB). Maintaining U.S. Leadership in Aeronautics: Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise. Washington DC: National Academy Press, 1997. (5 scenarios for the year 2025)

In order to assist in long-range planning, the NASA Office of Aeronautics asked the National Research Council (NRC) to conduct a workshop at which a number of experts from government, industry and the academic community considered possible futures for aeronautics over the next 25 years. A collection of sixteen different possible future scenarios were developed by combining the 'high' and 'low' conditions for four different variables that were judged to have a significant impact on aeronautics. These variables were:

1. U.S. economic competitiveness (weak or strong)
2. Worldwide demand for aeronautics products and services (low or high)
3. Threats to global security and/or quality of life (low or high)
4. Global trends in government participation in society (low or high)

Of the 16 possible scenarios, five were chosen as representing the most plausible futures:

1. "Pushing the Envelope" - strong competitiveness and aeronautics demand, low threats and government role
2. "Grounded" - strong competitiveness, low aeronautics demand, high threats and government role
3. "Regional Tensions" - weak competitiveness, high aeronautics demand, high threats and government role
4. "Trading Places" - weak competitiveness, high aeronautics demand, low threats and government role
5. "Environmentally Challenged" - weak competitiveness and aeronautics demand, high threats and government role

Workshop participants divided into five teams each of which developed a detailed depiction of each scenario and the role that aeronautics played in it. These scenario narratives were in turn studied carefully within NASA and used as inputs to help develop the agency's 1997 report, "Three Pillars of Success for Aviation and Space Transportation in the 21st Century."

US AIR FORCE

US AIR FORCE: Col. J. Engelbrecht, Lt. Col. R. Bivins, Maj P. Condray, Maj. M. Fecteau, Maj. J. Geis, Maj. K. Smith. Alternate Futures for 2025: Security Planning to Avoid Surprises. A research paper presented to Air Force 2025. April 1996. Available at http://www.au.af.mil/au/2025/monographs/A-F/a-f.htm. (4 scenarios for the year 2025).

In 1995, General Ronald Fogelman, Chief of Staff of the U.S. Air Force, tasked the Air University at Maxwell Air Force Base, Alabama “to look 30 years into the future to identify the concepts, capabilities and technologies the United States will require to remain the dominant air and space force in the 21st century.”[1] The Air University assembled a team of USAF personnel and academic and business leaders who, over a ten-month period, developed the Air Force 2025 report.[2]

As part of this report, the team developed scenarios representing possible futures. After considering more than 100 factors, or drivers, three were chosen as most relevant to the future environment of U.S. national security. They were:

- U.S. willingness and capability to interact with the rest of the world
- The growth rate of scientific knowledge and successful technological applications of that knowledge
- The generation, transmission, distribution and control of ‘power’, defined as the ability to influence the behavior of others in global events.

Based on analyses of these drivers, the team developed four plausible scenarios for 2025. They are:

- “Gulliver’s Travails” - in which the U.S. ability to deploy military power is constrained by a number of global players with other forms of power
- “Zaibatsu” - in which the world is dominated by multinational corporations
- “Digital Cacophony” - in which access to key information and technologies is widely dispersed among individuals and groups around the world
- “King Khan” - in which a resurgent Asia replaces the U.S. as the dominant world power.

In addition to these scenarios, the team also developed lists of the ten systems concepts and six technologies that represented the best investments for the U.S. to make to assure continued air and space dominance in the future. The ten top systems concepts were:

- Global Information Management System
- Sanctuary Base
- Global Surveillance, Reconnaissance and Targeting Systems
- Global Area Strike System
- Uninhabited Combat Air Vehicle
- Space High Energy Laser
- Solar High Energy Laser
- Reconnaissance Unmanned Air Vehicle
- Attack Microbots

1 A Quicklook at Air Force 2025 at http://www.au.af.mil/au/2025/quicklk.htm.
2 This report, issued in April 1996, and additional supporting documentation is available at http://www.au.af.mil/au/2025.

- Piloted Single Stage Space Planes

The six key high priority technologies for national investment are:

- Data Fusion
- Power Systems
- Micromechanical Devices
- Advanced Materials
- High Energy Propellants
- High Performing Computing

THE MILLENNIUM PROJECT

THE MILLENNIUM PROJECT of American Council for the United Nations University: 1998 State of the Futures: Issues and Opportunities. Available at http://www.geocities.com/~acunu/millennium/Millennium_Project.html (4 scenarios for the year 2052)

The Millennium Project of the American Council for the United Nations University describes itself as "a global participatory futures research think tank of futurists, scholars, business planners and policy makers who work for international organizations, governments, corporations, NGOs (Non-Governmental Organizations), and universities." These individuals undertake "a coherent and cumulative process that collects and assesses judgements [sic] from its several hundred participants" in order to produce regular and special reports such as an annual State of the Future report and special studies on specific topics and geographic regions.

The Project's 1998 State of the Future report, titled "Issues and Opportunities," used a futurist model to develop exploratory scenarios for how the world may look in 2052. The model developed sixteen future scenarios based on combinations of the extremes of four primary variables:

1. Degree of globalization (low or high)
2. Government involvement in society (low or high)
3. Communications technology (stagnant or vibrant)
4. Threats to global security and/or quality of life (low or high)

Of the sixteen possible scenarios, a process of discussions and polling chose four as representing the most plausible futures. They are called:

1. "Cybertopia" - computers and communications make a better world
2. "Rich Get Richer" - active intense economic competition gets our of hand
3. "Trading Places" - the developing countries flourish while rich nations stagnate
4. "Passive Mean World" - things get our of hand and the environment suffers major degradation

Values for population and per capita income, life expectancy, physical quality of life, and atmospheric CO_2 are calculated for each scenario, as well as a narrative description.

US DOT

US DOT: U.S. Department of Transportation. ONE DOT Scenario Strategy Workshop. April 1999. Available at http://stratplan.dot.gov/StratPlan/PlanProcess/Future.cfm (4 scenarios for the year 2028)

US DOT embarked on a scenario exercise as part of creating its second organizational Strategic Plan 2000-2005, published in July 2000. Scenarios were developed "to stretch thinking and generate discussion on the development of a more vigorous strategic plan" for the Department.[3] As described in the Strategic Plan 2000-2005, these scenarios …

> *….defined plausible and logically consistent stories of how the future might unfold with regard to the transportation enterprise. The scenarios allowed participants to think about and prepare for a wide range of realistic future possibilities within the constraints of 1) the economy, 2) globalization, 3) the role of government, and 4) demand for change in transportation.*[4]

The Department held a series of workshops, roundtables and interviews with hundreds of individuals who worked closely with it, as well as representatives of the wider transportation service provider and user communities. This process generated four scenarios for the world and the role of transportation within it in 2028, each of which reflected a different range of major drivers and their impacts. These four scenarios are called:

1. Aging America
2. Global Prosperity
3. Western Hemisphere
4. Global Climate Change

CIA

CIA: Central Intelligence Agency. Global Trends 2015: A Dialogue About the Future With Nongovernmental Experts. NIC 2000-02, December 2000. Available at http://www.odci.gov/cia/publications/globaltrends2015/index.html (baseline + 4 scenarios for the year 2015)

Global Trends 2015 was prepared by the National Intelligence Council (NIC) and based on an extensive series of conferences, workshops and outreach sessions with specialists both within and outside the Federal government as "a flexible framework to discuss and debate the future." It follows on the earlier Global Trends 2010 report, published three years earlier in 1997.

One of the major purposes of this project was to "make projections with varying degrees of confidence and identify some troubling uncertainties of strategic importance to the United States" and to provide a "longer-term, strategic perspective" on these issues over the coming years. The NIC identified seven key drivers that will, over the long term, shape the world in 2015. They are:

1. Demographics
2. Natural resources and environment

[3] Page 104.
[4] Ibid.

3. Science and technology
4. The global economy and globalization
5. National and international governance
6. Future conflict
7. The role of the United States

As part of the process of developing Global Trends 2015, the CIA's Global Futures Project and the State Department's Bureau of Intelligence and Research (INR) cosponsored a workshop of several dozen government, private sector and academic specialists in late 1999. This workshop developed four alternative global futures based on varying ways in which the major drivers identified above and other significant factors could interact and lead to substantially different outcomes. These four alternatives were called:

1. "Inclusive Globalization"
2. "Pernicious Globalization"
3. "Regional Competition"
4. "Post-Polar World"

Use of Scenarios in Socio-Economic Demand Forecasting

The scenario packages developed in these five projects, as well as other individual scenarios and collections from similar recent exercises, were assessed for common themes and factors that could affect economic growth and quality of life in both positive and negative directions. Special attention was paid to those factors that could most strongly impact transportation demand and service levels.

These previous scenario packages each developed several alternatives for how the future could unfold. The alternatives ranged from relatively unchanged projections of current trends to both highly optimistic and highly pessimistic views of what could occur. When these positive and negative scenarios were compared with each other, there were a number of similarities within them.

The positive high growth scenarios shared several characteristics, many of which reinforce each other as they unfold. They include:

- Sustained worldwide economic growth at a higher than predicted level (i.e., more than 3.1% per year globally), especially in the poorer nations
- Free international trade and financial systems with open markets and readily transferable investment capital
- Reductions in warfare, civil conflict, and international terrorism
- Adequate, low-polluting and affordable energy sources
- Overall reduction in fossil fuel emissions, resulting in declining levels of pollution and global warming

- Rapid expansion of Global Information Networks, including telephone systems and the Internet (i.e., a ‘Wired World’)

The negative, low growth scenarios also shared a number of mutually reinforcing characteristics:

- Lower than anticipated economic growth rates, with poorer regions of the world sinking even deeper into poverty

- Breakdowns in international trade and investment systems, often accompanied by the emergence of highly competitive, inwardly-focused regional trading blocs

- Continued global conflicts, civil disorder and terrorist incidents

- Scarce, costly and highly polluting energy sources

- Continued increases in pollution and greenhouse gases, often leading to catastrophic natural calamities due to global warming

- An increase in inequities, with richer nations monopolizing the benefits of improved technologies such as the Internet and aviation to themselves at the expense of the majority of the world’s population

From this analysis arose a collection of ‘enablers and constraints’ that represented those factors that could directly or indirectly impact the future of aviation as depicted in the current study in either positive or negative directions. These factors were then sorted into three categories:

1. Those factors that most directly impacted economic growth, as reflected in GDP growth rates;

2. Those factors that most directly impacted the cost of travel, as reflected in aviation yield; and

3. Those factors that impacted individuals’ decisions on which trips to take and what modes to use, or propensity to travel.

These factors and their possible impacts on the future of aviation demand are listed in Figure 1. SEDF Enablers and Constraints for Travel Demand Forecasting (next page).

Chart One: SEDF Enablers and Constraints for Travel Demand Forecasting

Item	**Low Growth Future**	Baseline **Future**	**High Growth Future**
1. Primary impact on GDP/population			
2005 to 2015	2.6%	3.1%	3.7%
2015 to 2025	2.6%	3.1%	3.5%
a. Level of mass population movements (migration, refugees)	High	Normal	Low
b. Level of global economic/financial integration	Low	Normal	High
c. Level of open international trade	Low	Normal	High
d. Extent of Global Information Network integration (telephone, Internet, TV, radio, etc.)	Low	Normal	High
e. Extent of global warming	High	Normal	Low
f. Impact of new successful 'Green' technologies	Low	Normal	High
2. Primary impact on yield w/ taxes			
2005 to 2015	0.0%	-1.35%	-2.0%
2015 to 2025	0.0%	-1.17%	-2.0%
a. Airline personnel costs (salaries, benefits, etc.); this equals wage rates divided by worker productivity	High	Normal	Low
b. Aviation fuel prices	High	Normal	Low
c. Network carriers adapt business models to changing industry conditions	Adapt poorly	Normal	Adapt very well
d. Cost savings from new and/or more efficient aircraft models introduced	Low	Normal	Moderate/high
e. Level of aviation taxes and fees	High	Normal	Low
f. Cost of capital for airports and airlines	High	Normal	Low
g. Level of competition	Low	Normal	High
h. Cost of environmental mitigation?	High	Normal	Low
3. Primary impact on other factors (propensity to travel, etc.)			
2015 effect relative to baseline (domestic/int'l)	-5%/-6%	0%	2.5%/3%
2025 effect relative to baseline (domestic/int'l)	-10%/-12%	0%	5%/6%
a. Perception about safety of aviation	More concern	Normal	Less concern
b. Perception about security of aviation (terrorism, etc.)	Not secure	Normal	Secure
c. Concern over environmental impact of aviation (global warming, emissions, noise, etc.)	High	Normal	Low
d. Attractiveness of telecommunications as an option to aviation	High	Normal	Low
e. Attractiveness of other transportation modes (rail, highway, etc.) as an option to aviation	High	Normal	Low
f. Lost time and inconvenience at airports due to surface congestion, security inspection delays, passenger/baggage processing delays, etc.	High	Normal	Low
g. Gap narrows between leisure and business travelers; ability to segment the market is reduced (long term effects only)	Leisure fares go up	Normal	Business fares fall more than leisure
h. Perception of risk of foreign destinations (terrorism, war, health, etc.)	High	Normal	Low
i. New aircraft models, e.g., SATS, RIA	Few	Normal	Many

THE BASELINE FUTURE

The baseline forecast of aviation demand utilized in this report is based on a continuation of current trends that impact aviation (primarily population and economic growth rates and the cost of travel) and the absence of both major global catastrophes and significant technological breakthroughs that could change either these trends or the overall world condition. Other recent scenario projects generated several scenarios that reflect roughly similar assumptions and projections of the future. They are summarized below.

Other Scenarios Projecting a Moderate Growth (Baseline) Future Situation

"Trading Places" (NASA, 1997)

Description and Key Variables:

- Asia (China, India, Pacific Rim) replaces U.S. as dominant economic power and focal point of manufacturing and R&D
- Businesses are globally competitive, with numerous international partnerships
- Open & harmonized trade environment and a 'wired world'
- China bypasses ground infrastructure and 'jumps' to aviation as major transport mode
- Many Asian tourists & businesspeople travel to U.S.
- Demand for aeronautics/space products is good

"Halfs and Half-Naughts" (USAF, 1996)

Description and Key Variables:

- Economic and technology growth benefits flow only to the 'haves' living in four dominant power blocs – the US, Europe, Russia and China
- Rapid technology development – telecommunications, pollution reduction, etc. -- benefits only the 'haves'
- The 'have nots' react with envy and resentment, fueling rises in crime, terrorism, regional conflicts and drug cartels
- Multi-national corporations gain influence
- Transport growth is mixed - higher in the power blocs but lower in the rest of the world

3. "Digital Cacophony" (USAF, 1996)

Description and Key Variables:

- Technology runs rampant, bringing both benefits and problems - definitely a 'wired world'
- Technology enfranchises individuals but disenfranchises organizations
- Public policy decisions are often made via 'electronic democracy'
- Virtual experiences replace many 'real' ones as terrorist and anarchic incidents increase and create high levels of personal anxiety

- New fuels found, pollution declines, food output soars
- Transport demand grows only slowly

4. "Trading Places" (Millennium Project, 1998)

Description and Key Variables:

- Global economic and political power shift to booming East Asian and Latin American economies. China replaces US as dominant world power
- US and Europe see sluggish growth and the mounting burden of caring for aging populations. Many jobs are low-wage, infrastructure crumbles, R&D shifts overseas
- Trade barriers drop, the 'nationality' of corporations becomes blurred
- Water shortages, increases in pollution and greenhouse gas emissions
- A stable world, with occasional flare-ups only in the poorest countries

5. "Western Hemisphere" (US DOT, 1999)

Description and Key Variables:

- Three regional economic alliances emerge, based in the Western Hemisphere, Europe and Asia
- US withdraws from World leadership, focuses on Western Hemisphere economic development & investment
- New fuels emerge, but many 'mega-cities' remain congested & polluted
- State/local governments control transport decisions, which somewhat inhibits interconnections
- Transport volume is mixed

6. "Global Trends 2015," 4 scenarios (CIA, 2000)

Description and Key Variables:

In their "Global Trends 2015" project, the CIA developed a depiction of the world in 2015, and then developed four "alternative global futures" based on this general depiction. The salient characteristics of their World in 2015 include:

- Information, materials, nano- and biotechnologies bring major breakthroughs, such as universal wireless connectivity, 'smart structures', biomedical engineering and genetic modifications
- Disaffected governments, terrorists, narcotraffickers and organized crime exploit these technological advances through such tactics as bioterrorism and cyberwarfare
- 'Globalization' -- the "rapid and largely unrestricted flows of information, ideas, cultural values, capital, goods and services, and people" -- triumphs

- Governments have declining authority, while businesses and nonprofit organizations have a growing influence

- Some areas -- North America, Europe, 'emerging Asia', parts of Latin America -- achieve sustained high levels of economic growth while other regions – the Middle East, Africa and Russia – are left behind and face stagnation, political instability, violence, and growing extremist movements

- Expanded use of fossil fuels, especially natural gas, exacerbates environmental problems. This stimulates the developed world to respond by conservation and switching to less polluting fuels (fuel cells, hybrid engines, solar, wind, etc.)

The four "alternative global futures" that could emerge from this background are:

- Inclusive Globalization - majority of population benefits from new technologies and economic growth, generally peaceful.

- Pernicious Globalization - Elites thrive, but the majority does not. World splits into developed (rich) nations, developing (poor) nations and a thriving 'illicit economy.' Conflict increases.

- Regional Competition - Europe, Asia and the Americas become preoccupied with themselves while the rest of the world is ignored, government authority grows, and internal conflicts increase.

- Post-Polar World - US stagnates, Europe turns inward. Asia thrives and becomes focal point of world economy, especially China.

Low Growth Future

Three alternative paths by which the world could reach a low growth future are described in chapter 4 of this report. The previous scenario exercises also developed alternative futures in which overall economic growth and transportation activity would be lower than depicted in the baseline forecast. They are described below.

Other Scenarios Projecting a Low Growth Future Situation

1. "Grounded" (NASA, 1997)

Description and Key Variables:

- Violence & terrorism rampant, which spurs the growth of the Internet (Global Information Network, or 'G-net') led by U.S. government

- 'G-net' becomes backbone of global economy and often substitutes for travel

- High cost of security drives public transportation costs up and usage down, including aviation

- Premium prices paid for low-volume high-priority air travel and air freight

- Demand for aeronautics/space products is down

-

2. "Regional Tensions" (NASA, 1997)

Description and Key Variables:

- Competing & antagonistic regional trading blocs emerge, centered on the US, Europe, China, and the rest of Asia
- ICAO & WTO no longer function, globalize in decline
- Government is interventionist - mobilizes the economy for potential conflict – and investments in aviation and space are heavily military
- Substantial international trade barriers, high inflation, slow economic growth, mounting government deficits
- Demand for aeronautics/space products is low (civil) and high (military)

3. "Environmentally Challenged" (NASA, 1997)

Description and Key Variables:

- Strict worldwide limits placed on CO_2, enforced by international organizations
- High political/civil instability
- Very high fuel taxes, weak U.S. economy, global recession, high unemployment, high inflation
- Companies' focus is regional, not international, due to high transport costs
- Ambivalent attitude to technology - is both 'cause' and 'cure' - focus is on energy/environmental problems
- Demand for aeronautics/space products is down

4. "Gulliver's Travails" (USAF, 1996)

Description and Key Variables:

- US is the only global power, but is constantly asked to intervene in foreign conflicts; US as world's policeman
- New nations appear; rampant nationalism, terrorism, fluid coalitions, constant low-level strife
- Evolutionary R&D, no new breakthroughs, emphasis on 'dual-use' technologies
- Sluggish economic and transport growth, hindered by strife and terrorism

5. "King Khan" (USAF, 1996)

Description and Key Variables:

- US is superseded as dominant global power by 'Greater China', US looks inwards

- Slow US economic growth, high deficits, high unemployment
- Slow rate of technology development, pollution worsens
- Transport growth slow in US, fast in 'Greater China'

6. "Passive Mean World" (Millennium Project, 1998)

Description and Key Variables:

- Population growth outpaces jobs everywhere, creating mounting economic and political pressure
- GNP growth stagnates, partially easing global warming concerns. Trade wars break out between Europe, Western Hemisphere and Pacific blocs
- People use the Internet to form common interest groups that ignore political and geographical boundaries
- By 2025 there is vast discontent, a distrust of governments and the UN, and large groups of homeless and migrating workers moving from country to country. Crime, wars and terrorism all grow
- India and China emerge eventually as the new global powers

7. "Aging America" (US DOT, 1999)

Description and Key variables:

- Public spending focuses on the elderly, who do well due to their dominant political power
- However, younger workers are hard-pressed by a combination of rising taxes, stagnant wages, high unemployment and deteriorating schools and social services for all but the elderly
- Protectionist trade barriers restrict imports
- Fewer people -- mostly the elderly and businesspeople -- are traveling
- In general, a frustrated society with high levels of internal tension.
- Transport volume is down

8. "Global Climate Change" (US DOT, 1999)

Description and Key Variables:

- Violent global weather underlies environmental and economic crisis. There is immense damage to coastal regions, agriculture and infrastructure; mounting social upheaval; slow growth; high unemployment; and large government deficits
- Governments impose controls to contain the crisis. These include demand reduction measures, energy conservation and CO_2 emission limits

- Long-distance trade and travel decline
- Much freight shifts from air and truck to rail and water modes
- Governments and individuals think locally, not globally
- Transport volume is down

HIGH GROWTH FUTURE

Three alternative paths by which the world could reach a high growth future are described in Chapter 4 of this report. The previous scenario exercises also developed alternative futures in which overall economic growth and transportation activity could be higher than depicted in the baseline forecast. They are described below.

Other Scenarios Projecting a High Growth Future Situation

1. "Pushing the Envelope" (NASA, 1997)

Description and Key Variables:

- Strong and growing global economy with rapid technological diffusion. Information technology (IT) is both ubiquitous and transparent
- Growing global middle-class
- Laissez-faire government, liberal trade policies
- Infrastructure expands, service costs drop
- Low cost access to space
- "The customer is king"
- Transport is privatized, 'smart' and harmonized
- Demand for aeronautics/space products is strong

2. "Zaibatsu" (USAF, 1996)

Description and Key Variables:

- Several large multi-national corporations have extensive power and work together to promote trade and profits
- This coalition of multinational corporations (Zaibatsu) assume many traditional roles of government and extinguishes local and regional conflicts as 'bad for business'
- High rates of economic growth, trade, technology development - a 'wired world'
- Highly efficient high-tech infrastructure for trade & travel (maglev, trans-atmospheric craft)
- Nuclear fusion and alternate fuels reduce both pollution and the importance of oil
- Strong transport growth

3. "Cybertopia" (Millennium Project, 1998)

Description and Key Variables:

- Explosive growth of technology and the Internet worldwide accelerates globalism. Billions spend most of their waking hours in cyberspace

- Education, employment, environment, health, energy and economic productivity all improve

- International organizations become useful facilitators for global standards and cooperation

- Gap between rich and poor narrows as ‘third-world’ citizens in ‘first-world’ countries help their native lands develop

- Democracy flourishes via on-line polls, voting and debates

4. “<u>The Rich Get Richer</u>” (Millennium Project, 1998)

<u>Description and Key Variables:</u>

- Headline - “Capitalists Save Civilization!”

- Some nations in South Asia, sub-Saharan Africa, Central & East Europe fall to the back of the development pack

- Inequities grow in first two decades, leading to corrupt government and wars

- Then, the largest ‘Trans National Corporations’ combine in 2020s to establish better conditions worldwide for the ‘market’ to flourish - health clinics, fair wages, ‘Say “No” to corruption!’, sustainable policies

- Conditions slowly start to improve afterwards

5. “<u>Global Prosperity</u>” (US DOT, 1999)

<u>Description and Key Variables:</u>

- “The business of the world is business.” Capitalism and technology triumphant; overall prosperity

- National governments lose power down (to states/regions), up (to international organizations and business cartels), and out (to the ‘market’)

- E-commerce spreads, cargo moves very efficiently thanks to ‘Global Logistics Giants’

- Huge business consortia determine new infrastructure

- Alternative fuel vehicles spreading rapidly

- Strong growth in transport volume

PREVIOUS SCENARIO COLLECTIONS CONSULTED FOR THIS REPORT

Drucker, Peter et al. "The Next Society: A Survey of the New Age". The Economist, November 3, 2001 (the world of the 2020s).

Ferguson, Niall. "The World on September 11, 2011, Ten Years After". New York Times. December 2, 2001 (the world in 2011).

Hammond, Allen. Which World: Scenarios for the 21st Century. 1997 (3 scenarios for 2050).

* Millennium Project of American Council for the United Nations University. 1998 State of the Futures: Issues and Opportunities. 1998 (4 scenarios for the year 2052).

* National Research Council, Aeronautics and Space Engineering Board (ASEB). Maintaining U.S. Leadership in Aeronautics: Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise. 1997 (5 scenarios for the year 2025).

Shell International. Energy Needs, Choices and Possibilities: Scenarios to 2050. 2001 (2 energy scenarios to 2050).

Shell International. People and Connections: Global Scenarios for 2020. 2002 (2 scenarios for 2020).

* U.S. Air Force (Engelbrecht, Col. J.; Bivins, Lt. Col. R.; Condray, Maj P.; Fecteau, Maj. M.; Geis, Maj. J.; and Smith Maj. K.) Alternate Futures for 2025: Security Planning to Avoid Surprises. April 1996 (5 scenarios for the year 2025).

* U.S. Central Intelligence Agency. Global Trends 2015: A Dialogue About the Future With Nongovernment Experts. NIC 2000-02, December 2000 (Baseline + 4 scenarios for the year 2015).

* U.S. Department of Transportation. ONE DOT Scenario Strategy Workshop. April 1999 (4 scenarios for the year 2028).

Wharton Business School, University of Pennsylvania. The post-September 11 Business Environment. 2001 (4 scenarios for 2001-2004).

Wingrove, E.; Hees, J.; Oberman, J.; Ballard, D.; and Golaszewski, R. Airline Scenarios for Transportation Demand and Economic Analysis. January 2003 (5 scenarios for the year 2022)

** Scenarios from these collections were cited in Appendix C.*

APPENDIX D. Embedded Delay Details

This analysis of embedded schedule delay does not distinguish between two types of schedule padding, padding to reflect delays expected by carriers due to anticipated congestion at some point in the itinerary, or padding intended to improve airline on-time performance. Instead, it is implicitly assumed that the former delay effect is the primary driver behind schedule padding. The basic approach taken in the analysis is to estimate a statistical regression equation that can account for scheduled block times as a function of such components as:

- Unimpeded taxi-out minutes (i.e., the expected taxi-out time if there were no delays)
- Expected departure delay minutes (= gate delay + taxi-out delay)
- Unimpeded airborne minutes
- Unimpeded taxi-in minutes
- Expected arrival delay minutes (= airborne delay + taxi-in delay)

A set of carrier/hub-specific dummy variables is also included to account for the effects of timing requirements at carrier hubs, which may affect published schedule times. For a given flight, a carrier is assumed to adjust the schedule for that flight based on the average delay faced by other flights at the same airport and in the same departure or arrival hour. Once the model coefficients are estimated, one can generate new predictions of the schedule times that would occur if average delays were reduced to zero. This provides a measure of the delay minutes that are embedded in the schedules.

Flight schedule data were used for four different seasonal months in calendar year 2000—February, May, August and November.[5] The data set included all scheduled flights within the continental US during those months. The dependent variable, observed scheduled block time, was taken directly from the *Official Airline Guide (OAG)* schedules. Average unimpeded taxi-out and taxi-in times were obtained from FAA, which maintains a database of unimpeded times broken out by airport, carrier and season.

Average departure and arrival delays by airport by hour are computed from a build-up of individual Aviation System Performance Metrics (ASPM) flight data, which covers all flights at 55 large US airports. By extension, flights to and from these 55 airports touch virtually all remaining US airports that appear in the *OAG*, so this allows us to compute average delay estimates at those airports as well. (Average delays at remaining airports are assumed to be zero.) It is assumed that carriers take the average of the prior three months' departure or arrival delay for the airport and hour in question. A priori, we might expect the coefficient on departure delay to be less than one—i.e., a one-minute increase in expected departure delay may lead to less than a one-minute increase in scheduled block time—because some of the lost time can be made up en route by flying faster. The effects of arrival delay should be larger since carriers cannot mitigate it as easily.

Changes in unimpeded taxi times should have close to a one-for-one impact on scheduled block times. For the present analysis, we have assumed that the taxi-out and taxi-in effects are the same, so we add the two measurements together to form a single independent variable, with an expected coefficient of near 1.

[5] The year 2000 was used to reflect a time period when the system was operating at high levels of demand in relation to capacity. It was believed that that schedules for 2001 and later reflect an abnormal downturn in flying due to the impacts of September 11.

The remaining independent variable—unimpeded airborne time—is not directly observable. Instead, it is assumed to be a function of three components—distance, equipment type, and weather effects. Distance is measured by the great-circle distance between the origin and destination. Three different equipment types are considered:

- 747/777 – cruising speed of .84-.86 Mach (label = FJET)
- Other jets (including RJs)—cruising speed of .77-.80 Mach (label = JET)
- Props (label = PROP)

These categories are interacted with the distance measure to yield three equipment-specific distance variables. We expect the coefficient on distance for FJETs to be positive (longer distances lead to longer scheduled times) but less than that for JETs, which in turn should be less than that for PROPs, since average speed declines as we move from fast jets to props.

There are many factors related to weather that might affect the scheduling of block times, including wind direction, temperature, altitude, etc. All of these effects can change along the entire flight path, but for scheduling purposes, carriers likely look only at average effects. The most important weather/direction effects in the continental US are the prevailing westerlies; flights headed from east to west are flying against the westerlies and so will take longer than those flying west to east. A good proxy for this directional effect is the initial bearing (relative to magnetic North) assuming a great-circle flight path. (Although the directional bearing changes all along the great-circle route, tests with other possible measures—e.g., rhumb-line bearing, which stays constant but is not along the great-circle route—yielded virtually identical results.) The raw bearing measurement was modified so that flying due west has a bearing measure of +1; due east has bearing of –1, and north/south flying is measured as zero; these modifications imply an expected positive sign on the coefficient. This measure is interacted with the equipment-specific distance variables because flying into or with the wind on longer routes will obviously affect total schedule time more than on shorter routes. Because the westerlies effect varies by season (they are much stronger in the winter), separate regressions were estimated for each season using the monthly data described above.

As shown in Figure 1-31, all equations explain a very large portion of the overall variability in observed schedule times (R2 > 0.97). Moreover, all coefficients shown in the table have the expected signs and are statistically significant. The expected ordering of the distance variables by equipment type is also satisfied. The coefficients on the departure delay variables are around 0.16, implying that a one-minute increase in expected average departure delay causes carriers to increase their schedule time by only .16 minutes; this is consistent with the idea that carriers can take measures to mitigate the effects of departure delays on overall block times. On the other hand, the coefficients on arrival delay range from 0.8 to almost 1, suggesting that carriers build in average arrival delays on an almost one-for one basis. The taxi time coefficients are also close to 1, as expected.

Figure 1. Regression Coefficients for Determinants of Scheduled Block Time and Implied Embedded Delay for Year 2000

	Feb-00	May-00	Aug-00	Nov-00
Constant	15.766	15.896	15.887	17.150
Distance if FJET	0.116	0.116	0.116	0.116
Distance if JET	0.122	0.121	0.120	0.121
Distance if PROP	0.177	0.178	0.179	0.179
Dist*Bearing if FJET	0.011	0.009	0.007	0.012
Dist*Bearing if JET	0.014	0.011	0.007	0.013
Dist*Bearing if PROP	0.014	0.013	0.013	0.011
Unimpeded Taxitime (out and in)	1.052	1.005	0.952	0.954
Avg Departure Delay	0.152	0.157	0.161	0.169
Avg Arrival Delay	0.795	0.879	0.946	0.949
(Carrier hub dummies not reported)				
Adj R-squared	0.979	0.986	0.983	0.984

Embedded Delay results using initial bearing as direction variable.
Data covers all scheduled flights in Lower 48 states.

APPENDIX E. Demand Forecasting Literature Review

INTRODUCTION

Demand for commercial air transport is considered a "derived demand." That is, demand for air travel is the consequence of satisfying some other compelling interest, such as engaging in business or leisure activities. Unlike demand for many other goods, transportation services are not directly linked to demand for some final product. Therefore, forecasting demand for commercial air transport requires considering the variables that determine or "drive" that demand. These variables include socioeconomic determinants, such as growth in the economy, income, and population, and service determinants, such as airfares, seat availability, flight frequency, and the availability of transportation substitutes.

Our literature review assesses academic, institutional, and industry models of demand for air travel (including the demand for cargo air services) to determine which variables best explain air travel demand and how these variables can be used to forecast air travel demand. Although many of the studies we reviewed consider commercial air travel between particular markets, in this review we emphasize aggregate demand for air travel and forecasts of that demand in the United States. We reviewed FAA forecasts of national demand for commercial air transportation as a standard method for forecasting air travel. In addition, we reviewed academic and other studies that have assessed the variables that determine demand for air travel. The variables most often used for predicting air transport demand were GDP and yield. Some other variables commonly used are airfares, oil prices, and population.

FAA FORECASTS

We reviewed two annual FAA forecasts: *The FAA Aerospace Forecasts: 2003-2014* and the *Terminal Area Forecast.* The FAA aerospace forecast is a comprehensive forecast of the entire aviation industry, including commercial air travel (domestic, international, and commuter/regional), cargo transport, general aviation, and the workload at FAA control towers and other facilities. The Terminal Area Forecast (TAF) emphasizes enplanements and operations at FAA-towered and contract-tower airports in the United States.

FAA AEROSPACE FORECASTS

Because the most recent FAA Aerospace Forecast[6] and its associated methodology are described in detail in the body of this report, we do not duplicate that information here.

TERMINAL AREA FORECAST

The FAA TAF[7] "provides aviation data users with summary historical statistics on passenger demand and aviation activity" (i) for individual airports. These data then are used for forecasting passenger demand and airport activity, such as enplanements and operations. TAF covers 266 FAA-towered airports, 180 radar-approach control facilities and 3,031 non-FAA-towered and non-towered airports. Although the specific variables used to forecast aviation activity in TAFs are not enumerated, the process as described appears similar to the process used in the aerospace forecast.

> Aviation activity forecasts at FAA-towered and contract towered airports are developed using historical relationships between airport activity measures and local and national factors influencing aviation activity. (2)

[6] Federal Aviation Administration, *FAA Aerospace Forecasts: Fiscal Years 2003–2014,* Washington, DC, 2002, (FAA-APO-03-1).

[7] Federal Aviation Administration, *Terminal Area Forecast Summary*, Washington, DC, 2001 (FAA-APO-01-7).

International Civil Aviation Organization (ICAO)

The *North Atlantic Air Traffic Forecasts for the Years 2002–2007, 2010, and 2015*[8] reports short-, medium-, and long-term forecasts of air traffic and annual forecasts for total passengers and aircraft movements. The report includes forecasts for peak and off-peak periods.

The ICAO North Atlantic Traffic Forecasting Group compiled annual estimates of passengers and aircraft movements from numerous data sources, e.g., Transport Canada, the U.S. Immigration and Naturalization Service Form I-92, the U.S. Department of Transportation Form T-100, NAV EP Air Navigation Statistics from Portugal, the Official Airline Guide, International Air Transport Association (IATA) data for travel from Europe to Central America/Caribbean, and air traffic counts from the Gander and Shanwick centers. Because of the effects of September 11, 2001, the method used for forecasting 2002–2003 traffic on North Atlantic routes are modified (and hence, not discussed here) compared to methods for forecasting 2004–2007, when the passenger demand for air travel is assumed to return to previous long-term annual growth rates.

The Forecasting Group forecasted the North Atlantic scheduled passengers for 2004–2007 using an econometric model that used the total of North American GDP and European GDP as its exogenous variable as well as a dummy variable for terrorism. The model forecasts 70.4 million passengers in 2007 (5.0% annual increase over the 6-year forecast period). The Forecasting Group then used the passenger demand projections and the group's assumptions about average seat size and load factor for generating the annual scheduled flight forecasts for 2004–2007. They project that in 2007, the scheduled flights will be 340,300 (annual 4% increase over the 6-year forecast period).

The Forecasting Group projected non-scheduled passenger travel demand using assumptions about the non-scheduled carriers' future share of total passengers. They then used assumptions about the average aircraft seat size and load factor for deriving the forecasts for non-scheduled flights.

Under the assumption that Europe to Central America/Caribbean passengers and flights were largely unaffected by the events of September 11, the Forecasting Group used the same method for the entire forecast period. They used an econometric model relating passenger demand of this region to economic activity in Western European countries for forecasting passenger demand for 2002–2007. They used a higher load factor and larger aircraft assumptions for forecasting flights for this region.

The Forecasting Group projected growth rates for cargo-only flights using an econometric model relating cargo-only flights to the total of North American and Europe GDP. They forecast general aviation (GA) flights forecasts on the assumption that the cutback in scheduled passenger service for years 2002 and 2003 will positively affect GA.

ICAO: Outlook For Air Transport to the Year 2010

The 2001 ICAO publication, *Outlook for Air Transport to the Year 2010*,[9] reaffirms that the demand for air transport is determined primarily by economic development, personal income levels, and changes in airline costs. The study prepares the traffic forecasts using economic analyses of the effects of underlying factors on aggregate demands for air passenger and freight traffic. The study begins with a detailed summary of air transport trends and challenges, including the world economic outlook and airline financial trends.

The study then describes the forecasting method and main assumptions used in developing the econometric models. The ICAO models are based on the following assumptions:

[8] International Civil Aviation Organization, The North Atlantic Traffic Forecasting Group, 33rd Meeting, May 7–May 16, 2002, *North Atlantic Traffic Forecasts for the Years 2002–2007, 2010, 2015*. Paris, France, 2002.

[9] International Civil Aviation Organization, *Outlook for Air Transport to the Year 2010,* Montreal, Canada, 2001 (Cir 281).

- Average rate of world economic growth will be 2.5% per annum (real terms).
- Moderate growth in world trade will be 4.0% per annum.
- Average passenger freight yields will decline 0.5% per annum from the year 1999–2004, and will not change from 2004–2010 for the world as a whole.
- Adequate capital resources will be available for developing aviation and tourist infrastructure. (32-33)

The first two econometric models developed in this study are of passenger traffic and freight traffic. (47) Both models assumed the basic form:

$$y = a\, x_1^{b1} * x_2^{b2}. \qquad \text{[Eq. 1]}$$

where for the model of passenger traffic:

y = passenger-kilometers performed (PKP)
x_1 = GDP in real terms
x_2 = passenger revenue per passenger-kilometer in real terms (PYIELD)

and for the model of freight traffic:

y = freight tonne-kilometers (FTK)
x_1 =world exports in real terms (EXP)
x_2 = freight revenue per freight tonne-kilometer in real terms (FYIELD)

The constant coefficients a, b_1, and b_2 were obtained by statistical estimation. The b_1 and b_2 are the elasticities of demand with respect to the corresponding x_1 and x_2. Both models have a high predictive strength as shown by the R^2 statistics.

Passenger model:

$$ln\ PKP = 0.017 + 2.19\ ln\ GDP – 0.50\ ln\ PYIELD \qquad \text{[Eq. 2]}$$

$$R^2 = 0.999.$$

Freight model:

$$ln\ FTK = -0.27 + 1.57\ ln\ EXP – 0.39\ ln\ FYIELD \qquad \text{[Eq. 3]}$$

$$R^2 = 0.996.$$

Aside from assessing the future trends of passenger and freight traffic flows, assessments of trends in aircraft movement are necessary for planning aviation facilities and developing aviation policies. Aircraft movements depend primarily on the demand for passenger travel so the passenger traffic forecasts derived from the previously described models are the key inputs to the aircraft movement forecasts.

Southern Californian Association of Governments

The Regional Airport Demand Allocation Model (RADAM)[10] generates current and forecast air passenger and cargo demand and then allocates them to airports. The first step is generating the demand using the available airport origin-destination (O-D) data (for current demand) and applying the correlated data to the Southern Californian Association of Government (SCAG) forecast data for each RADAM zone (for forecast demand). Some of the socioeconomic factors for correlating the data are total population and employment, retail and high-tech employment, median household income, disposable income, household size, number of households, and licensed drivers per household. Catalytic or induced demand, representing an increased propensity to fly because of convenience or quality of service, also is calculated in the model. Therefore, the regional demand total is a variable that depends on airport capacity and service around the region.

The variables that most influence the airport choices for different air passenger categories (short-, medium-, long-haul passengers; international passengers; and business, pleasure, and exclusive tour passengers) are the following:

- Total number and frequency of flights
- Nonstop destination served
- Number of discount airlines
- Travel time from home or work
- Travel time from hotel or convention center
- Ground access congestion
- Air fare
- Terminal congestion and convenience
- Parking costs
- Airport mode choice options and convenience

The researchers also determined the cross elasticity between variables.

After they generated the forecast demand, the researchers allocated the demand by matching major airport attributes with primary airport choice factors for different passenger groups. This step allocates the total passengers from each passenger category to each airport in each RADAM zone.

Community Air Service Analysis

The Community Air Service Analysis (CASA)[11] is a range of analytical methods derived from the MacNeal Air Service Scale (MASS) model. The MASS model answers questions about air passenger traffic, schedules, fares, airport accessibility, geographical distribution, and underlying demand. Specifications of the model vary depending on the issue to be addressed. Both scale and analytical methods can be used. For example, to represent the quality of round-trip air service, a scale of numerical values is used where lower values represent better service. The scale measures

[10] National Academy of Sciences, Transportation Research Board, *Aviation Demand Forecasting; a Survey of Methodologies,* Washington, DC, 2002 (E-Circular E_C040), pp. 16-18.

[11] Ibid, pp. 18–20.

services from the most frequent nonstop pattern through different qualities of single-plane service and connections. “The scale measures the pattern of round-trip services versus desired departure times, taking equipment type, stops, connections, connection time, circuity [which measures how directly the traveler was routed from his origin to his destination], and distance into account. Number of flights (frequency) and seats (capacity), as such, are ignored.” (19) Changes in one variable will reinforce or offset the other variables. Using simple analytical techniques and standard factors, CASA can be used for any airport situation.

If, for example, the objective is to analyze service distribution between multiple airports in a region, then it can be done in the following three steps:

1. Calculate the air service area.

2. Compute the underlying relative demand for air service for each zone in each service area (normally this relative demand is a product of a zone population divided by income group and the propensity to travel by income group).

3. Use the relative demand to produce a realized demand taking into an account factors, such as airport accessibility to the population, the level of air service available, and the fare levels.

These models have been used for airports and regions in more than half of the 50 states.

INTERNATIONAL FORECASTS

International Passenger Traffic Forecasting

TDS Economics developed a model[12] that is based on econometric analyses and relies on cross-sectional and time-series data. This model forecasts international aviation activity. Data is collected about flights between specific O-D pairs and economic and
demographic factors that influence the demand for aviation (GDP, population, prices, interest rate, and fuel cost). Data sources are government and international aviation entities (e.g., FAA, ICAO), international trade associations (e.g., IATA and the Association of European Airlines), airports, and published schedules. A model used to develop country-level forecasts may take the following form:

$$\text{Dependent variable} = \alpha + \beta\,\text{GDP} + \gamma\,\text{Yield} + \varphi\,\text{GDP Other Countries} + \text{Other Explanatory Variables.} \qquad \text{[Eq. 4]}$$

or

$$\text{Dependent variable} = \alpha + \beta\,\text{GDP/Population} + \gamma\,\text{Population} + \lambda\,\text{Yield} + \varphi\,\text{GDP Other Countries} + \text{Other Explanatory Variables.} \qquad \text{[Eq. 5]}$$

“Models that are designed to forecast airport-to-airport or country-to-country operations often take the form of:

$$\text{Dependent variable} = \alpha + \beta\,\text{GDP1} + \gamma\,\text{GDP2} + \gamma\,\text{Yield} + \text{Other Explanatory Variables.} \qquad \text{[Eq. 6]}$$

where GDP1 and GDP2 represent regional or country income or other measure of economic activity.” (22)

[12] Ibid, pp .21–23.

International Passenger Traffic Forecasting: True O-D

Travel Insight, Inc. has developed a model[13] that produces detailed air passenger traffic forecasts taking into an account every possible passenger flow over an international route at any U.S. gateway airport. The model determines the volume of international traffic from any geographical area. The forecasting process is done in the following six phases:

1. Determine the O-D for the nonstop flight.
2. Define the states whose traffic could flow over the nonstop segment on connecting services.
3. Define the countries beyond the foreign gateway to which traffic could connect.
4. Identify the markets that the target carrier or alliance partners serve behind the U.S. gateway and beyond the foreign gateway.
5. Establish maximum and minimum growth rate limits for different categories of city-pair markets.
6. Establish stimulation assumptions as necessary. (23-24)

The data used in the forecast model comes from Travel Insights' international O-D database covering 1991 through 2001. Using the 10-year time-series data, the model generates growth rates for every individual market.

International Air Cargo Forecasts

DRI-WEFA has developed a model[14] for forecasting international air cargo volumes, focusing on 77 commodities categories that constitute total international merchandise trade. Cargo movements are linked to economic indicators from the O-D of each commodity. The demand for each commodity is estimated using a pooled cross-sectional time-series approach based on historical and country-specific information. Each commodity group has its own global forecasting model with inputs, such as real GDP, incomes, consumption, investment, prices, population, employment, and share of goods traded. The data inputs for the forecasting models come from trade statistics from the U.S. Census Bureau, United Nations, and the Organization for Economic Cooperation and Development. These models are useful for analyzing policy and long-term planning of infrastructure.

INDUSTRY FORECASTS

Firms and groups in the aerospace industry forecast aviation activity to make long-term business plans. Boeing, Airbus Industrie, Rolls Royce, the IATA, and others, such as airlines and equipment manufacturers, produce annual forecasts. Industry models provide an interesting insight into using demand forecasting. In general, these models use a narrow range of determinants and substantial subjective knowledge.

Boeing Current Market Outlook

Boeing produces forecasts of passenger demand as part of its forecast of demand for aircraft.[15] The Boeing model relies almost entirely on changes in economic growth. According to Boeing, "The majority of air traffic growth is explained by economic growth. International trade, airline service improvements, and declining fares explain additional portions of traffic." (9) Boeing uses regional

[13] Ibid, pp. 23–25.

[14] Ibid, pp. 25-26.

[15] Boeing Commercial Airplanes, *Current Market Outlook*, Seattle, WA, 2001. http://www.boeing.com/commercial/cmo

forecasts of GDP to develop regional and global forecasts of demand for air travel, which it then incorporates into its forecast of demand for aircraft.

Airbus Global Market Forecast

Airbus Industrie produced its Global Market Forecast (GMF) for 2000–2019 in July of 2000.[16] In the Airbus forecasts, passenger traffic depends primarily on economic growth (changes in GDP) and changes in real fares. Passenger traffic is forecast to grow at an average annual rate of 5.2% during the next 10 years and slow down to an average of 4.6% in the following decade. Cargo traffic will grow more rapidly than passenger traffic because cargo traffic will be stimulated by an increase of global e-commerce and manufacturing trends. (4)

Rolls Royce

Rolls Royce, a manufacturer of commercial aircraft engines, created outlook forecasts for 2001–2020.[17] The report states that the future airline service patterns depend on numerous factors. Economic cycles are a key factor. "The airline industry sometimes magnifies economic cycles, as consumer or business confidence can swing very rapidly towards or against discretionary travel. An immediate consequence of weaker demand for air travel is lowering of passenger yields in many markets, as airlines attempt to maintain capacity utilization (i.e., load factors) using yield management." (26)

Snecma

Snecma Moteurs prepared the commercial aircraft market forecast for 2000–2019.[18] The fact that the economic factors are the main concerns for the future demand growth is another proof of the tight relationship between transportation and the economy. Other variables that may affect the growth trend of air transportation are the following:

- Oil prices
- Political factors, such as the enlargement of the European Union to Eastern European countries and political choices of the Chinese government
- Social factors, such as increases in the elderly population in Europe
- Environmental factors, such as the greenhouse effect of aviation and the potential obligation to comply with the Kyoto protocol. (29)

BAE Systems

BAE Systems' 2000 annual report has a concise review of the economic aspects of the aviation market.[19] It begins with a section that describes the historical information for the main indicators of the level of competition in the European air transport industry. Following sections are dedicated to factor outputs and the financial performance of the industry. Business cycles and oil prices are used to explain airline profitability trends. (4-1) A section of the report is devoted to European and transatlantic fares development. The continued decline of the Euro and rising market costs might have been a reason for the lack of fares reductions between July 1999 and July 2000. (5-10)

The report also contains a very detailed section about the industry structure, route structure, and airports. The report ends with a section about traffic forecasts perspectives. BAE obtained the data

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[16] Airbus Industrie, *Global Market Forecast 2000–2019,* Bagnac Cedex, France, 2000. www.airbus.com

[17] Rolls Royce, *The Outlook: 2001–2020,* Derby, Great Britain, 2001. www.the-outlook.net

[18] Snecma Moteurs, *Commercial Aircraft Market Forecast 2000–2019*, Moissy-Cramayel, France, 2000.

[19] BAE Systems. Updating and Development of Economic and Fares Data Regarding the European Air Travel Industry, 2000 Annual Report (Prepared for the EEC, Directorate General Energy and Transport). http://europa.eu.int/comm/transport/themes/air/english/library/annual_report_2001_v2.pdf

they used in this section from a survey of industry participants done by the IATA. “In 2000, there were 81 participants…(they) were asked to provide actual scheduled passenger numbers for 1999; estimated passenger growth rates at a country-pair level for each year from 2000–2004; and average annual growth rates for 2005–2009 and 2010–2014.” (9-1) Some of the conclusions based on this data are that the North Atlantic will continue as the busiest route into and out of Europe, that the dominant routes in terms of passenger numbers will be between the UK and the U.S., and that routes between Europe and Russia should increase.

International Air Transportation Association

The IATA produces a 4-year forecast of regional and global passenger traffic annually, based on forecasts produced internally by IATA members.[20] A survey of methods used to generate these forecasts provides insight into the factors considered when forecasting demand for air travel. Among members surveyed, 70% do forecasts that are unconstrained by airport and airspace restrictions, two-thirds of the forecasts rely on internal data (the remaining one-third rely on government data), and the majority use quantitative models instead of quantitative-qualitative or hybrid methods. Most forecasting models used one or two variables (about two-thirds), although no model used more than five variables. The factors most often used to forecast demand are the following:

- Economic growth—used in more than 75% of models
- Competition—used in almost 50% of models
- Fleet Changes—used in about 45% of models
- Yield—used in about 40% of models.

ACADEMIC RESEARCH ON AIR TRANSPORT DEMAND FORECASTING

Academic research about the factors that influence demand for commercial air transport generally divide the factors into two categories: socioeconomic and quality of service. The FAA Aerospace Forecast model uses only economic variables (GDP growth and yield). Other models, such as the commonly used gravity model, use both economic and demographic data from the city-pairs or origin and destination markets being studied. More recent studies have emphasized variables intended to illustrate the quality of service offered by commercial air carriers as a determinant of demand. The studies we review below are divided into those that use only socioeconomic variables and those that include the effects of service quality on demand for air transport.

Socioeconomic Determinants of Demand

Volpe Center[21]—The socioeconomic determinants of demand most often considered include the population, income, employment characteristics, and wealth of the markets as well as the cost of air travel between those markets, represented by fares or yields. The Volpe National Transportation Systems Center uses a simple model that relies on socioeconomic data to determine the effects of technological change on demand for air travel (Volpe). This model is specified below:

$$\begin{aligned} &\textit{Air passengers}_{ijt} = B_0 + B_1 * \textit{yield}_{ijt} + B_2 * \textit{distance}_{ijt} \\ &+ B_3 * \textit{income}_{it} * \textit{income}_{jt} \quad \text{[Eq. 7]} \end{aligned}$$

Where,

[20] International Air Transport Association, Passenger Forecast 1998–2002, Montreal, CA, 1998.
[21] Volpe National Transportation Systems Center, “The Volpe Air Forecasting Model.” Cambridge, MA, no date.

air passengers represent the passenger trips between the two cities that are taken in a given year (t)
i and j represent city pairs
t = 1979, 1983, 1988, 1992
income represents the personal income of each city considered.

The results showed that the coefficients varied significantly over trip distances and, therefore, the model is specified over three distance segments. The distance variable is included only to represent these segments in the model. The coefficients exhibited expected patterns of price elasticity but consistent income inelasticity.

Alperovich and Machnes (1994)[22]—This paper studied the effects of wealth on demand for international air travel from Israel. The authors note that most studies that include income use current income data, rather than permanent income. "This practice…is at odds with economic theory which suggests that permanent rather than current income is the relevant variable which determines demand." (163) They also observe that many models suffer serial autocorrelation and presume that this may be the result of not including wealth variables in the model to capture the effects of permanent income. The model divides wealth into financial and non-financial assets to determine if asset liquidity affects demand. Data were collected between 1970 and 1989. The model is specified below:

$$lnD_t = \alpha_0 + \alpha_1\, ln(P_t/PI_t) + \beta_0\, ln(W_t/PI_t) + \beta_1\, ln\,(FA_t/PI_t) + \beta_2\, ln(NFA_t/PI_t).$$

[Eq. 8]

where

D_t = Ratio of air travelers by population
P_t/PI_t = Real price of travel
W_t/PI_t = Real wages
FA_t/PI_t = Real financial assets
NFA_t/PI_t = Real non-financial assets

The model explained about 98% of the variation in the ratio of travelers by air and did not exhibit serial autocorrelation. Demand for international air travel proved price inelastic but income elastic (real wages). While the model showed that demand for travel is wealth inelastic, the wealth coefficients were statistically significant. The authors conclude, "The results…provide solid support for the fundamental hypothesis that demand for international travel is determined, other things being equal, by consumers' wealth." (169)

Vilain (1998)[23]—This paper modeled enplanements at Bradley International Airport (BDL) in Hartford, CT, to determine if the U.S. market for air transportation is reaching the saturation point, or the point of maturity, at which growth in passenger demand will no longer exceed GDP growth but trend with or lag behind it. Vilain uses different specifications of the model, changing the form of the variables to capture the functional form of demand for air travel (a standard log-log model, a logarithmic reciprocal transformation, simple reciprocal transformation).

The basic models are shown below:

a. $ln\,(ACP) = \alpha o + \alpha 1\; ln\,(TOTEMP) + \alpha 2\; ln\; YIELD + u.$ [Eq. 9]

b. $ln\,(ACP) = \alpha_o + \alpha_1\,(1/TOTEMP) + \alpha_2\,(1/YIELD) + u.$ [Eq. 10]

[22] Alperovich, Gershon and Y. Machnes. "The Role of Wealth in the Demand for International Air Travel," *Journal of Transport Economics and Policy* 28(2): 163–173, 1994.

[23] Vilain, Pierre, "Is Market Saturation in the Airline Industry Upon Us?" Paper presented to the annual meeting of the Transportation Research Board, January 1998.

c. $(ACP) = \alpha o + \alpha 1 \ (1/TOTEMP) + \alpha 2 \ (1/YIELD) + u.$ [Eq. 11]

where:

ACP = air carrier enplanements
TOTEMP = total employment in the BDL market area
YIELD is average revenue per passenger mile at BDL

Each model explained about 98% of the variation in enplanements. Although the standard specification and the logarithmic reciprocal transformation showed no maturation and long-term maturation, respectively, the simple reciprocal transformation showed immediate maturation of the U.S. air transport market. However, this specification is the least theoretically accurate of the three.

Quality-Of-Service Determinants of Demand

Quality-of-service determinants attempt to account for factors specific to the routes being studied or to the industry as a whole that affect the demand for air transport. These factors include available seating capacity on aircraft, the number of stops required to reach a destination, and the time and frequency of flights.

Melville (1998)[24]—This author uses a two-step method to determine demand for air transport between the U.S. and UK and Caribbean states. The first stage requires determining quality-adjusted fares using a hedonic pricing model. Hedonic pricing theory "postulates that observed price is a function of the characteristics of the product or service." (317) Using the hedonic pricing model to produce quality-adjusted fares "purges the observed price of all variation arising from changes in quality attributes. The quality adjusted price represents pure price movements." (317) Quality-adjusted fares are determined by the number flights between city-pairs (FLIGHTS) and the number of stops per flight (STOPS), as specified below:

$$LFARE_{it} = \alpha_0 + \alpha_1 FLIGHTS + \alpha_s STOPS + u_{it.} \quad \text{[Eq. 12]}$$

International travel, unlike domestic travel, is subject not only to typical socioeconomic and quality-of-service factors, but variables that arise because of differences in prices and exchange rates between destinations. Melville includes the real effective exchange rate (exchange rate adjusted for differences in inflation) in his model to account for this effect. He also introduces dummies to represent different city pairs and different years to capture city-pair-specific effects and the effects of factors common across city pairs but varying through time. Finally, Melville includes the dependent variable lagged one period among the explanatory variables, assuming that in any period, the change in passenger demand is an adjustment to previous changes in the independent variables (partial adjustment hypothesis). The full model is specified below:

$$\mathrm{LPASS}_{it} = \alpha_0 + \alpha_i + \tau_t + \beta_1 \mathrm{LPASS[-1]}_{it} + \beta_2 \mathrm{QFARE}_{it} + \beta_3 \mathrm{LRINC}_{it} + \beta_{it} \mathrm{LREER}_{it} + \beta_{it} \mathrm{PCRGDP}_{it} + e_{it.} \quad \text{[Eq. 13]}$$

where

α_i = fixed city pair effects
T_t = time effects
LPASS = volume (bi-directional) of passengers (log) on city pair
QFARE =quality adjusted fare (residual of hedonic price function)
LRINC = product of per capita incomes (U.S. $) of countries on route deflated by weighted average of consumer price index (logs)
LREER = real effective exchange rate (log)
PCRGDP =percent change in real GDP of endpoint countries

[24] Melville, J. A, "An Empirical Model of the Demand for International Air Travel for the Caribbean Region," *International Journal of Transport Economics* 25(3): 313–336, 1998.

The results show that the lagged passenger variable and real income are statistically significant at the .10 level and the quality-adjusted fare is statistically significant at the .05 level and illustrates the expected negative sign. According to the author, "If the only service quality indicators available are flight frequency and routing, no major mis-specification occurs by using unadjusted fares to estimate the demand function." (328)

Ghobrial (1993)[25]—This study models the origin-destination demand between U.S. and foreign gateways. He uses a gravity demand model in which demand for air travel between U.S. gateway, "i," and foreign gateway, "j," is expressed in terms of socioeconomic variables and service characteristics of air transportation between the gateways. The theoretical model is expressed below:

$$T_{ij} = f\,(D_{ij},\, Si_{ij},\, G_i,\, G_j). \qquad \text{[Eq. 14]}$$

where

T_{ij} = demand between gateways
D_{ij} = vector of socioeconomic characteristics of passengers
S_{ij} = vector of transport supply variables between i and j
$G_i,\ G_j$ = gateway-specific variables of O-D gateways

The socioeconomic variables considered in the model include population and income per capita, airfare, distance, and market-specific variables. Quality-of-service variables considered include frequency, aircraft size, and number of stops. Airfare and distance were dropped because of lack of data and colinearity with distance and seating capacity and correlation with aircraft size, respectively. Gateway-specific variables are expressed as dummies. The model is expressed below:

$$\mathrm{T_{ij}} = \alpha \mathrm{F_{ij}}^{\beta}\ \mathrm{ST_{ij}}^{\gamma}\mathrm{Y_i}^{\varphi}\ \mathrm{P_i}^{\lambda}\ \exp(\mu \mathrm{SP_{ij}} + \eta \mathrm{TR_{ij}} + \sigma \mathrm{NYC} + \delta \mathrm{LAX} + \theta \mathrm{MIA} + \omega \mathrm{LON} + \psi \mathrm{FRA})\varepsilon. \qquad \text{[Eq. 15]}$$

where

T_{ij} = weekly passenger demand between gateways i and j
F_{ij} = weekly flight frequency between i and j
ST_{ij} = average aircraft capacity (seats)
Y_i = average income per capita in city i
P_i = population in city i
SP_{ij} = number of stops between i and j
TR = dummy variable for tourist markets.

Among these variables, flight frequency, aircraft size, and number of stops were significant at the .05 level and income per capita was significant at the .10 level. Demand was elastic with respect to number of stops (negative coefficient) and income (positive coefficient).

Kaemmerle and Dresser (1988)[26]—This paper explores the methods available for forecasting demand for air transport and develops a model for forecasting demand for small-community air service. Their study begins with a detailed discussion of gravity model theory, simple trend analysis, market-share analysis and structural and econometric models. They also include an exhaustive review of literature up to the date of the study.

The authors then consider numerous variables related to both socioeconomics and quality of service through a step-wise fashion. The dependent variables, enplanements and enplanements per capita, are regressed over these variables in two steps that require estimating the model for each

[25]Ghobriel, A., "A Model to Estimate the Demand Between U.S. and Foreign Gateways," International Journal of Transport Economics 20(3): 271–283, 1993.

[26] Kaemmerle, Kenneth C. and George B. Dresser, *A Methodology for Estimating the Demand for Small Community Air Service,* College Station, TX, Texas Transportation Institute, 1988.

type of dependent variable without service characteristics (community only) and with both service and community characteristics. The result is four equations that specify the model differently. In addition, the model incorporates five economic base groups among the community characteristics to illustrate differences in demand according to the economic base that exists in an O-D market. The four specifications of the model are shown below:

a. *Enplanement model without service characteristics*

$$ln\ ENPL = \alpha + \alpha_1\ ln\%MGR + \alpha_2\ lnPOP + \alpha_3\ lnPCI + \alpha_4\ lnAFCT + \mu. \quad \text{[Eq. 16]}$$

b. *Enplanement model with community and service variables*

$$ln\ ENPL = \alpha + \alpha_1\ lnINC + \alpha_2\ lnAFCT + \alpha_3\ lnDEPC2 + \alpha_4\ LARGE + \alpha_5\ HUB + \mu. \quad \text{[Eq. 17]}$$

c. *Enplanements per capita without service characteristics*

$$ln\ ENPLPC = \alpha + \alpha_1\ ln\%MGR + \alpha_2\ lnHHINC + \alpha_3\ lnAFCT + \mu. \quad \text{[Eq. 18]}$$

d. *Enplanements per capita with community and service variables*

$$ln\ ENPLPC=\alpha+\alpha_1\ lnINC+\alpha_2\ lnHHINC+\alpha_3\ lnDEP2+\alpha_4\ lnFAREMI2 +\alpha_5\ LARGE +\alpha_6\ HUB + \mu. \quad \text{[Eq. 19]}$$

where:

ENPL = enplanements
ENPLPC = enplanements per capita
% MGR = percent of population in management or professional position
POP = population in markets
PCI = per capita income
AFCT = hub airport attractiveness factor (distance to hub)
INC = income
DEPC2 = weekly departures per capita to all hubs
LARGE = dummy for aircraft size (> 30 seats)
HUB = dummy for hub/not hub
HHINC = percent of households with incomes $\geq$ \$35,000.

Among the four specifications, (b) showed the greatest predictive strength, with the model explaining 80% of the variability in enplanements. The weakest specification was (c), with the model explaining 25% of the variability in enplanements per capita. Whether the dependent variable was enplanements or enplanements per capita, the models including quality-of-service characteristics were the strongest. In specification (b), aircraft size was nearly unit elastic, indicating that capacity constraints may be important in determining demand for air transport.

According to the authors, "The most interesting conclusion drawn from the analysis is support for the general hypothesis that community characteristics alone cannot explain the variation in the use of air service among small communities in the United States." (82) The authors conclude with the following caveat

> …there is a circuity in the logic of using service variables to explain the use of air service. Increased enplanements will result in an increase in the number of departures, certainly an increase in the number of available seats assuming that acceptable load factors are maintained. However, air service planners also know that the demand for service is influenced by the quality of service provided. The frequency of departures is an important measure of service quality. (82)

Geoffrey I. Crouch[27]—This study identifies systematic differences between long-haul and short-haul tourism, if the differences exist. Since the end of the Second World War, international travel and tourism has grown substantially. Many studies have been done to identify the factors that caused this growth in international travel. According to some of the studies, the growth is attributable to numerous factors, such as an income elasticity of demand that is high; a price elasticity that is high; decreases in travel costs; and increasing urbanization, population, education, and leisure time.

This study uses meta-analysis to integrate the empirical findings of 80 studies of international travel demand. The majority of the studies produced results in a form of demand elasticities (% change in demand caused by a 1% change in its determinant) but some studies reported their results in the form of a time-trend coefficient (an annual fractional change in demand over the study period after the effects of other causal variables are accounted for).

The differences between long-haul and short-haul travel are significant. Increased cost and increased time of travel are some of the more obvious differences. The study begins with the following hypotheses:

> "H1: The income elasticity of demand for long-haul tourism exceeds the income elasticity of demand for short-haul tourism […]
>
> H2: The price elasticity of demand for long-haul tourism is lower than the price elasticity of demand for short-haul tourism
>
> H3: Similarly, the exchange rate elasticity of demand declines as length of haul increases […]
>
> H4: Long-haul tourism is more sensitive to changes in the cost of transportation […]
>
> H5: International tourism demand is more sensitive to the promotion of destination in case of long-haul travel […]
>
> H6: The net growth in long-haul tourism exceeds the net growth in short-haul tourism" (3-4).

The meta-analytical approach has a few advantages to the traditional narrative review of literature because it identifies the underlying patterns in the findings and corrects the distribution of findings for the effects of study artifacts, such as variances caused by sampling error. The meta-analytical approach in this study investigates the variation in results for a set of empirical studies and corrects the mean and variance of the estimated elasticities for artifactual effects.

The results of meta-analysis suggest that both long-haul and short-haul international tourism are income elastic implying that international tourism is a "luxury." Long-haul travel has lower price elasticity. The exchange rate elasticity of short-haul tourism is higher than that of long-haul tourism.

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[27] Crouch, Geoffrey I, "Demand Elasticities for Short-Haul versus Long- Haul Tourism," *Journal of Travel Research,* 33(2): 2–7.

> Tourists appear to be significantly more sensitive to the cost of transportation to long-haul destinations. […] The effects of promotion may also appear to be greater in the case of long-haul tourism as hypothesized. The underlying or net growth in long-haul tourism also seems to be greater than the net growth in short-haul tourism. (5-6)

The results are evidence that long-haul tourism is more subject to changes in real income, the real cost of transportation, and promotional expenditures. Long-haul tourism seems to be more dependent on changes of fashion and trends than short-haul tourism.

Wesley H. Long (1970)[28]**—**This study identified three principal travel motivations: Good trips (trips made to obtain goods and services from the destination city), business trips (meetings, planning sessions, and sales), and visit trips (personal visits to friends and relatives). Demand for the good trips function can be expressed as:

$$G_{ij} = G_{ij}\,(Q_{ji}) \qquad (i \neq j;\ i, j = 1,\ \ldots,\ n) \qquad \text{[Eq. 20]}$$

where:

G_{ij} = number of goods trips from city i to city j
Q_{ji} = the quantity of city goods offered at city j that are demanded by residents of city I

"Economic theory usually places one restriction on a demand function: that it be homogeneous of degree zero in prices and income." To implement this restriction, each variable in the function can be divided by the city goods mill price of the trip destination, yielding the following

$$G_{ij} = G_{ij}\,(Q_{ji}) = G_{ij}\,(M_1/M_j,\ C_{i1}/M_j,\ \ldots,\ M_n/M_j,\ C_{in}/M_j,\ Y_i/M_j) \qquad \text{[Eq. 21]}$$

$(i \neq j;\ i, j = 1,\ \ldots,\ n)$" (354)

where:

M = mill price of city goods at one of n cities
C = the cost of passenger transportation between the city of origin and one of the destination locations
Y_i = disposable income of the population of city i

Business trips are a common reason for travel. In this study, the assumption is that business travel depends on the size of trip origin and destination: the larger the population of a city, the larger the number of firms in that city. The following equation is the demand function for business trips:

$$B_{ij} = B_{ij}\,(P_1,\ \ldots,\ P_n,\ C_{in})\ (i \neq j;\ i, j = 1,\ \ldots,\ n) \qquad \text{[Eq. 22]}$$

where:

B_{ij} is the number of business trips from i to j
P is the population of origin, destination, and alternative destination

Demand for visit trips is a function of income, transportation cost, and population. The function for demand for visit trips is as follows:

$$V_{ij} = V_{ij}\,(P_1,\ \ldots,\ P_n,\ C_{i1}/Y_i,\ \ldots,\ C_{in}/Y_i)\ (i \neq j;\ i, j = 1,\ \ldots,\ n) \qquad \text{[Eq. 23]}$$

[28] Long, Wesley H, "The Economics of Air Travel Gravity Models," *Journal of Regional Science*, 10(3): 353–363, 1970.

where V_{ij} is the number of visit trips from *i* to *j*.

The three demand functions discussed above cannot be estimated separately because data on inter-city travel by purpose of trip is unavailable. Therefore, a combined function must be used:

$$T_{ij} = G_{ij} + B_{ij} + V_{ij} = T_{ij}\,(M_1/M_j,\ C_{i1}/M_j,\ \ldots,\ M_n/M_j,\ C_{in}/M_j,\ Y_i/M_j,\ P_1,\ \ldots,\ P_n,\ C_{i1},\ \ldots,\ C_{in},\ C_{i1}/Y_i,\ \ldots,\ C_{in}/Y_i) \quad (i \neq j;\ i, j = 1,\ \ldots,\ n). \qquad \text{[Eq. 24]}$$

The model, which focuses on origin, destination, and alternatives, is called the alternative opportunities model. On the other hand, the gravity model deals only with origin and destination. To produce a function of a gravity model, certain changes have been made to the alternative opportunities model (i.e., distance is substituted for transportation cost).

The results of the gravity model regressions suggest that the larger the per capita income was, the more air trips would be taken. The regressions also suggest, as expected, that the more distant the alternative cities are from the origin, the higher the number of air trips to the given destination. When looking at the mill price ratios between the origin and destination cities, the results suggested that the higher the mill price at the city of origin, the more air trips. However, a variable representing mill price ratios of alternatives to the destination city had a negative sign implying that the higher mill prices of alternatives (relative to destination), the lower the number of trips to the destination.

Philip Howrey (1969)[29]—This paper aids its readers in selecting the appropriate forecasting model for air travel according to the presented empirical evidence. The importance of the paper is that it may prevent the expenses of unnecessarily collecting and manipulating data by identifying models that have a low forecasting precision.

To assess the forecasting precision of a model, this study did two tests using data from 1960 and 1965. The first test compares the stability of parameter estimates for the two samples.

> The second test that is used to evaluate the cross-sectional travel modes involves *ex post* predictions. Using the coefficient estimates obtained from the 1960 cross section, the actual values of the independent variables from the 1965 cross section are used to predict the 1965 travel flows. If the predictions do not have the required accuracy, then there is little hope that the cross-sectional models will be useful for *ex ante* predictions. Moreover, the abstract model must perform significantly better than the gravity model in order to justify its use for prediction. (216)

The general form of a gravity model is the following:

$$T_{ij} = f(P_i,\ P_j,\ D_{ij}) \qquad \text{[Eq. 25]}$$

where:

T_{ij} is a number of trips between cities *i* and *j* per unit of time
P_i and P_j are the populations of the two cities
D_{ij} is the distance between the two cities

This model can be applied to the travel volume by all modes or to each mode separately. If it is applied to each mode separately, than the gravity model takes the following form:

$$T_{ijk} = f_k(P_i,\ P_j,\ D_{ij}) \qquad \text{[Eq. 26]}$$

[29] Howrey, E. Philip, "On the Choice of Forecasting Models for Air Travel," *Journal of Regional Science*, 9(2): 215–224, 1969.

where k represents travel by mode k

A simple abstract mode model takes the following form:

$$T_{ijk} = f(P_i, P_j, C, H, F) \quad \text{[Eq. 27]}$$

where C, H, and F are functions of cost, trip time, and frequency of departure, respectively.

The results of the gravity model regression analysis imply that "the gravity model with trip time as impedance factor gives the best fit to the data." (218-219) The model happened to be better at explaining the 1965 data than the 1960 data.

This model performed well for both test years. The Chow test was used to test for significant differences in the regression coefficients between the two years. The test determined that the hypothesis that the structure has not changed between the two years could not be rejected at the 95% level.

The main conclusion is that improving on the predictions of a simple gravity model is difficult. Although the abstract mode model did produce higher coefficients for the 1960 cross section, it was less effective in producing the accurate *ex post* predictions for 1965. The author also concluded that the predictive accuracy of the abstract mode model depends on the form of the model that is specified. "Of the five forms of the abstract mode model that were explored here, four were rejected on the basis of significant differences in the 1960 and 1965 parameter estimates. The only abstract mode model that survived the structural change test produced *ex post* forecasts inferior to those of several forms of the simple gravity model." (223)

APPENDIX F. Economic Impacts of Aviation Literature Review

INTRODUCTION AND OBJECTIVES

Transportation plays a major role in economic development and economic growth of every part of the world. It allows separate regions to connect and form a larger market area. There are numerous advantages of increased market areas. One of the advantages is that a unity of two of more market regions through transportation implies an increase in the demand for goods and services in each region. Such an increase in demand allows economies of scale to be realized as more goods are produced using the same amount of inputs. Transportation is also a key ingredient for the survival and continuous growth of international trade.

Improvements in transportation (due to infrastructure improvements, vehicle efficiency, etc.) are likely to lower transportation costs. Since transportation is an input-related cost, lower transportation costs would also increase competition. Air transportation is the fastest way of moving people, goods and services and is becoming increasingly important in economic growth of regions with access to air transportation services. The main purpose of this literature review is to identify the link between the economic activity of a region or a country and the availability of air transportation. More specifically, the available literature was reviewed in order to determine what information is obtainable on the following topics:

- Economic Impacts of Aviation
    - Present economic impacts
    - Future economic impacts
- What do studies say about current impact on US economy?
    - Magnitude?
    - What is included?
- International Trade Impacts of Aviation
- Measuring Benefits of Investment in Aviation Infrastructure
- What does OMB say about using economic impact measures, if anything?
- What do studies say about benefits of future investment?
    - How are they measured?
    - What is their magnitude?
- What are key assumptions?

LITERATURE REVIEW

Source: Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs

By: Office of Management and Budget (OMB)

Date: 1992

Topics covered: What does OMB say about using economic impact measures, if anything?

The purpose of reviewing this document is to identify the economic measures recommended for use in Federal benefit-cost analyses by OMB. The Circular applies to "…any analysis used to support Government decisions to initiate, renew, or expand programs or projects which would result in a series of measurable benefits or costs extending for three or more years into the future." (2)

One of the general principles of benefit-cost analysis is *net present value*. Net present value is the discounted monetized value of future expected net benefits. It is calculated by assigning monetary values to future benefits and costs and then discounting these values using an appropriate discount rate. Programs with positive net present value are generally preferred because their net benefits exceed the net costs.

Net present value estimates should be based on *incremental benefits and costs*. Sunk costs and realized benefits should be ignored. *Interactive effects* are effects of interactions between the benefits and costs being analyzed and other government activities. The interactions need to be considered when preparing an analysis. The benefit-cost analysis should focus on estimating only the impacts on the citizens of the United States. If a program or project has *international effects*, these effects should be reported separately. The net present value calculation should not include transfer payments because no economic gains or losses result from transfer payments.

If the benefits and costs are measured in real terms, then a real discount rate should be used. A real discount rate is approximated by subtracting expected inflation from a nominal interest rate. If the benefits and costs are measured in nominal terms, then a nominal discount rate that reflects expected inflation should be used.

"Constant-dollar benefit-cost analysis of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7%. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years." (8) When there is uncertainty about the appropriate discount rate, analyses may include an estimation of the *internal rate of return* or the discount rate that sets the net present value of the program to zero. The *shadow price of capital* is the analytically preferred method of capturing the effects of government projects in resource allocation in the private sector.

When measuring benefits and costs, market prices should be used whenever possible. If market prices are distorted or unavailable, measures should be derived from actual market behavior. There are three concepts to be considered when measuring benefits and costs: inframarginal benefits and costs, indirect measures of benefits and costs and multiplier effects. *Inframarginal benefits and costs* relate to the concept of consumer surplus. Consumer surplus measures the extra value that consumers derive from consumption of a good or service compared to the market value of that good or service. *Indirect measures of benefits and costs* refer an indirect measurement of willingness to pay through changes in land value, variation in wage rate, etc. *Multiplier effects* and their treatment in the guidelines are of special interest to this literature review. The Circular states "…analyses should treat resources as if they were likely to be fully employed. Employment or output multipliers that purport to measure the secondary effects of government expenditures on employment and output should not be included in measuring social benefits or costs." (6) Without guidance on the assumptions behind a multiplier effect estimation, as well as guidance on other economic impact measures, the calculated net benefits of a proposed program or projects could be overestimated or underestimated.

Source: Economic Impact of U.S. Airports

By: Airports Council International

Date: 2002

Topics covered: Economic impact of aviation. What do studies say about the current economic impact on U.S. economy

This study describes the dependency of national, regional, and local economic growth on the U.S. airport industry:

- “Airports create $507 billion each year in total economic activity nationwide.
- There are 1.9 million jobs on airports in the U.S., and 4.8 million are created in local communities, or 6.7 million airport-related jobs. These jobs translate into earnings of $190 billion.
- Airports generate $33.5 billion in local, state, and federal taxes.

- Over 1.9 million passengers each day rely on U.S. airports for business and leisure travel, and over 38,000 tons of cargo goes through U.S. airports each day. (1)

The study reviewed airport economic impacts reported in the 2001 ACI-NA Airport General Information Survey and FAA Aerospace Forecast, Fiscal Years 2000-2011, and reported that the total U.S. airport-related employment is forecast to increase from 6.7 million in 2001 (actual) to 9.9 million in 2013. Total U.S. airport economic related activity is forecast to increase from $507 billion (actual, 2001) to $750 billon in 2013.

The U.S. airport industry has grown significantly between the year of publication of the previous “Economic Impact of U.S. Airport" report in 1997 and the year 2001, the year of publication of this report. The total economic output created by the airports increased from $379.7 billion to $506.5 billion, representing a 33% increase. Employment in the airport industry increased by 0.9 million or 16% from 1997 to 2001. During the same time, earnings increased from $155.5 billion to $190.2 billion.

The economic impacts of airports are significant because airports generate wealth, employment, and taxes. The airport economic impacts can be categorized as direct, indirect, and induced impacts. Direct impacts are consequences of economic activities carried out by entities with direct involvement in aviation (airlines, airport management, etc.). “Indirect/induced airport impacts are consequences of economic activities that supply on-airport business, off-airport business activities associated with airport through-put (i.e., hotels, restaurants, travel agencies, etc.), or the impact resulting from successive rounds of spending in local community.” (7)

Source: The National Economic Impacts of Civil Aviation

By: DRI-WEFA, Inc., A Global Insight Company in collaboration with The Campbell

Hill Aviation Group, Inc.

Date: July 2002

Topics covered: Economic impact of aviation. What do studies say about the current economic impact on U.S. economy? International trade impacts of aviation. Benefits of investment in aviation infrastructure. What do studies say about benefits of future investment?

The purpose of this study is to provide insight into the contribution of civil aviation to the U.S. economy. In addition, the study analyses the economic and employment costs of congestion and delay. Civil aviation and its impacts, as defined in this study, consist of:

- Scheduled and unscheduled commercial passenger and cargo operations

- General aviation (including business aviation and air taxi)

- Related manufacturers, servicing, and support (including pilot and maintenance technician training)

- Their supply chains

- The effects of income generated (induced impacts) directly and indirectly by civil aviation

- The direct, indirect, and induced impacts of related industries, such as travel and tourism. (6)

Civil aviation impacts (by category) on the economy for the year 2000 are presented below:

- Direct Impact: $343 billion and 4.2 million jobs were produced directly in civil aviation or in industries related to civil aviation. Excluding related industries, civil aviation directly produced $181.8 billion in GDP and 2.2 million in jobs.

- Indirect Impact: $255 billion and 3.2 million jobs were created indirectly in the other industries in the supply chain to civil aviation and related industries.

- Induced Impacts: $305 billion and 3.8 million jobs were created as the income generated by civil aviation was spent.

- Total Impact: $904 billion in GDP and 11.2 million jobs were generated as a result of civil aviation's impact on the economy. Of this, general aviation generated $102 billion in GDP and 1.3 million jobs. (6)

Campbell-Hill analyzed the costs of congestion delays and concluded that in the year 2000, commercial airline passenger delays were 142 million hours annually and caused $4.7 billion in annual costs to passengers and $4.7 billion in annual costs to the economy. The results of the Campbell-Hill analysis imply that the cost of delays to economy equals 1.51 times the cost of delay to air carriers in order to include the induced cost to airlines. The total cost of delay, to passengers and economy, in the year 2000 was $9.4 billion. Given current investment plans, delays and related costs would rise to 185 million hours and $12.2 billion annually in 2007, and to 231 million hours and $15.2 billion annually in 2012. (11) In this analysis, it was assumed that all non-runway projects (i.e., terminals) neither enhanced nor constrained airport capacity.

The reduction in congestion costs derived from aviation infrastructure investment represents the public benefit. Public returns on investments are computed by comparing that public benefit to the infrastructure capital cost. This study analyzed the costs of congestion delays in 2007 and 2012 compared to 2000 using five scenarios:

1. Baseline: No new investment after 2000

2. Committed or fully committed airport infrastructure and air traffic control technology (based on the FAA OEP version 3).
    a. 2007/2012 airports: Current scheduled runway expansion as forecasted by the FAA. This case adds 16 new runways.
3. Moderate expansion of investment in airport infrastructure and air traffic control technology:
    a. 2007/2012 airports: The committed scenario plus runway extensions at Fort Lauderdale –Hollywood International (FLL) and Philadelphia International (PHL) airports equaling 18 new or extended runways.
    b. 2007/2012 air traffic control: New technologies for all 55 large FAA OPSNET airports are available on their forecast dates by 2012.

4. Aggressive: Aggressive expansion in investment in airport infrastructure and air traffic control technology:
    a. 2007/2012 airports: "All runways in the Moderate scenario are finished, and the remaining 15 planned runways are fully implemented at their expected completion dates including, by 2012, runways that have not been assigned a forecast in-service date (i.e., 'to be determined').
    b. 2007/2012 air traffic control: New air traffic control technologies available in the moderate scenario for commercial passenger OPSNET airports by 2012, but after 2007, are now available by 2007." (10-11)
5. Accelerated expansion if investment in airport infrastructure and air traffic control technology:
    a. 2007/2012 airports: The Moderate scenario plus full implementation of the additional 15 runways added by the Aggressive scenario and accelerated to 2007.
    b. 2007/2012 air traffic control: All new technologies available by the year 2007 at commercial passenger OPSNET airports.

It is calculated that, for example, in the aggressive scenario, the investment in air transport infrastructure would reduce projected 2012 passenger delays by 64 million hours or 25%. Every dollar of investment would generate as much as $5 in economic benefits to the U.S. economy.

The aviation industry has a significant impact on international trade. "In 1999, 8.4 million Americans traveled oversees for business, including conventions" (21). Air cargo is also an important sector of the industry. The growth of global air cargo undeniably increases with international trade activity. Exports of goods and services represent almost 25% of the world's GDP while U.S. merchandise trade amounts to 22% of the world total. Air transportation is also directly linked to international tourism. "The total of air travel and travel-related spending, $94.7 billion in 1999, has grown 62% since 1990, when international visitors spent about $58.3 billion in travel and travel-related expenses to visit the United States. … The amount of spending is significant (the International Trade Administration—the source of these figures—estimates that foreign travel in the United States in 1999 supported over 1.1 million of U.S. jobs), and exceeds the amount spent by Americans visiting other countries by $13.9 billion.

The global competitiveness of U.S. industries is negatively affected by an increase in production costs added to American businesses and caused by aviation congestion. It is interesting to note that air cancellation and delays impose costs that may actually appear as increases in GDP. This increase caused by delay and cancellations may be due to, for example, spending on additional meals away from home, additional hotel accommodations, etc. Indirect costs of delay/cancellations to the individual are a result of opportunity cost of time. Aviation congestion imposes numerous costs to the society in a form of air pollution caused by increased fuel burn of aircraft using a congested airport, congestion on roads as well as air pollution are increased if travelers avoid delays by departing from a less convenient airport, delays increase the cost of doing business and this cost is then passed on to consumers in the form of higher prices leading to a decrease in economic activity, etc.

Source: Economic Impact of Civil Aviation on the U.S. Economy

By: J. Robbins Tucker, Air Traffic Control Association Conference

Date: July 9, 2002

Topics covered: Economic impact of aviation. What do studies say about current impact on US economy?

The purpose of this study is to provide a quantitative understanding of the role of Civil Aviation in the U.S. economy. Civil aviation includes the following five elements:

1. Airline services
2. General aviation
3. Civil airport operations
4. Aircraft manufacturing
5. Aviation passengers
   a. Hotels
   b. Food and beverages
   c. Entertainment, etc.

There are four types of economic impact from civil aviation (these measures of economic impact overlap):

1. Economic activity: Total expenditures related to air transportation and related businesses
2. Earnings: Wages and salaries
3. Jobs
4. GDP

Economic activity caused by civil aviation is composed of direct, indirect, and induced impacts. The following are the year 2000 estimates of each component of economic activity of the United States, as well as the estimates for earnings and jobs:

1) Economic Activity

Direct Impacts ($Billions):

Airline Operations: $106.4

Airport Operations: $ 15.8

General Aviation: $ 10.9

Aircraft Manufacturing: $ 38.6

Subtotal: $172.7

Indirect Impacts ($Billions):

Airline Passengers:	$204.5
General Aviation Passengers:	$ 3.0
Travel Agents:	$ 6.3
Other General Aviation:	$ 1.5
Subtotal:	$215.3

Induced Impacts ($Billions):

From Direct:$337.6

From Indirect:	$386.3
Subtotal:	$723.9
Total Impacts ($ billion):	**$1,111.0**

2) Earnings ($Billions): $316.6

3) Jobs (Millions): 11.6

Finally, the following are the estimates of the impact of aviation on the U.S. economy for the year 2000 expressed as contribution to GDP:

Impact Type	GDP Contribution (Billions)	Percent of GDP
Direct	$171.8	1.7%
Indirect	$215.4	2.2%
Induced	$126.4	1.3%
Total	$513.5	5.2%
U.S. Total GDP	**$9,872.9**	**100%**

Source: A Methodological Proposal to Analyze the Economic Impact of Airports

By: G. Montalvo

Publication: International Journal of Transportation Economics, Vol. XXV-No.2

Date: June 1998

Topics covered: Economic Impacts of Aviation. What do studies say about current impact on US economy? What is included?

This study provides a survey of the main methodologies used in estimating the economic impact of an airport on a particular area. The majority of literature considers the airports' importance in terms of transportation benefits or in terms of the economic impact that a particular airport or a system of airports have on a local, national, or world level. The transportation benefits approach is similar to the cost-benefit analysis and includes benefits such as time savings, cost avoidance, transportation safety, etc. The economic impact of airports is classified in three categories: direct, indirect, and induced impacts.

One of the basic methodologies in assessing the economic impact of airports is the differential estimation approach. It is closely related to a concept of opportunity cost and implies that economic impact studies should only measure those activities that would not have happened if the airport did not exist. That is to say, if the workers employed at the airport could have been employed elsewhere without expelling other workers, they should not be included in assessing the economic impact of that particular airport. Unfortunately, such an estimation is often unfeasible and unpractical.

The following is a description of the basic methodology to measure the economic impact of airports. The economic impact of airports is the effect of the airport's activity (and other related activities) on output, income, and employment. Some problems arise when assessing the economic impact of airports. The first problem is the definition of regions affected by the airport: the larger the area, the weaker the effect. The choice of the year is also important for calculating the total economic impact. If an economic impact study is done during a peak year, the total impact will be overestimated while a study done during recession would underestimate the average impact.

This study looked at a 1986 FAA publication, "Measuring the Regional Economic Significance of Airports," and an ACI (1993) publication "the Economic Impact Study Kit," for activities included under the definition of "direct impact." "[T]he main activities included [indirect impact] are:

Government:

- Security
- Immigration services
- Customs
- Department of agriculture
- Civil aviation authority
- Post office

Airport operator or authority:

- Airport administrator
- Airport maintenance
- Airport private security
- Fire brigade
- Air traffic control
- Weather forecast services

Airlines and aviation services providers:

- Airlines
- Aircraft maintenance
- Air cargo
- Passenger and ground handling
- Flight catering
- Fuel service
- Aviation schools

Commercial sector:

- Tax free shops
- Restaurants
- On site hotels
- Car rentals and car parking
- Retail shops
- Currency exchange
- Financial services on site

Ground transportation:

- Taxis
- Buses" (189-190)

Indirect impacts are a product of economic activities of off-site firms that serve airport users (hotels, restaurants, travel agencies, shops, etc). In order to assess the indirect impacts of an airport, a passenger survey (for non-residents) is often conducted with questions relating to their expenses at the final destination and trip purpose.

"Induced impacts are the result of the multiplier effect of direct and indirect impacts generated by their recipients. For instance, an airport worker, with his salary, buys a car. That generates income for the car seller that he could spend in buying a TV. This will generate the income for the TV seller, etc." (193) Induced economic impact can be evaluated using three categories of methodologies:

1. The economic base model that relies on differentiating between goods sold within a region (non basic or services) and goods sold out of the regions (basic).

2. The econometrics model, which is a macroeconomic model of the regional economy, that takes into account consumption, income, taxes, public expenditures, etc.

3. The input-output methodology: "Its main advantage is the consideration of sectoral differences in the calculation of the multipliers. The disadvantages are essentially related with the large amount of data needed to construct the input-output tables." (194)

The input-output methodology is the most common approach in assessing regional economic impact of an airport.[30] The total impact is calculated as a sum of direct, indirect, and induced impacts.

Source: Job Flight and the Airline Industry: The Economic Impact of Airports in Chicago and Other Metro Areas

By: William A. Testa

Publication: Federal reserve Bank of Chicago

Date: 1992

Topics covered: Economic Impacts of Aviation

As the title suggests, the main purpose of this study is to estimate the economic impact of airports on Chicago and other metro areas. To do so, it is important to make a distinction between "economic impact" and "economic benefit." Economic impact usually includes items that are not net benefits to society while at the same time excluding other important benefits such as the value of passenger time. The study begins with an extensive assessment of previous economic impact studies related to Chicago area airports. Economic impact studies serve an important function of

[30] For U.S. airports, the most common source of input-output multipliers is the RIMS II system developed and managed by the Bureau of Economic Analysis in the U.S. Department of Commerce.

informing the public of the linkages between air travel and regional economies. However, the public should be aware of the fact that many of the linkages are difficult to quantify and are therefore neglected. One of the economic impacts of airports is that it induces foreign investment because in deciding on facilities locations within regions, access to air travel can be important to foreign offices and investment.

Expenditures by tourists and business visitors are also an important source of economic activity that is in large due to the availability of airports in the region. There are three categories of business travel, as reported by the Chicago Convention and Visitors Bureau: conventions, trade shows, and corporate meetings. "Estimates made by the International Association of Convention Bureaus report that [trade] show visitors spend the most money during visits and stay the longest period of time." (15)

Another important component in economic activity of a region is the availability of air cargo services. "Many of the heaviest users of domestic air freight display high concentrations of employment in the Chicago area as of 1986 … These include medical instruments, communications equipment, instruments, printing and publishing, general industrial equipment and machinery, drugs and pharmaceuticals, electronic equipment, and photographic equipment and supplies." (16-17)

The study points out the need to reduce Chicago airports' capacity constraints in order to assure the healthy growth of regional economy.

Source: The Contribution of the Aviation Industry to the UK Economy

Publication: Oxford Economic Forecasting

Date: November 1999

Topics covered: Economic Impacts of Aviation. International Trade Impacts of Aviation

This study points out the economic benefits of the aviation industry. It illustrates in detail the contribution of the aviation industry to economy of the UK using a number of different measures. The contribution of the aviation industry to GDP is calculated as follows:

- The value added by airlines in 1998 is £5.3 billion (1995 prices) and is equivalent to 0.8% of UK GDP.
- The value added by the air transport supporting activities was £2.5 billion in 1995.
- It was estimated that in 1998, the aviation industry helped support 550,000 jobs in the UK. Of these, 180,000 direct jobs were responsible for creating 200,000 indirect jobs. Spending by direct and indirect employees created 94,000 induced jobs (about 25% of direct and indirect jobs). Finally, it was assumed that about 80% of the work of employees in travel agencies is associated with arrangements of air travel. There are about 94,000 employees in travel agencies and tour operators; this means that about 75,000 jobs are supported by the aviation sector.
- Tourism is of great importance to the UK economy. The study used the following assumptions in calculating the number of jobs created by overseas tourists:
    - Surveys were used to determine the total spending in the UK by the visitors arriving by air from overseas, and what proportion of it was spent on different items.

- The spending of visitors was calculated as a share of total spending in the UK
- It was assumed that the same proportion of relevant employment is attributable to the spending of foreign visitors.

This approach implies that about 200,000 jobs in the UK are attributable to the spending by visitors arriving by air from overseas.

The financial contribution of the UK aviation to the government's revenue is also sizable. It includes: Income taxes from aviation; the national insurance contribution from aviation; corporate tax revenue from airlines; corporate tax revenue from airports; and air passenger duties. In 1998, the breakdown of air transport contribution (£ million) to balance of payments in the UK was as follows (21):

- Exports 6,631
    - Passenger revenue 4,422
    - Freight revenue 408
    - Disbursements[31] 1,505
    - Other revenue 296
- Imports 8,069
    - Passenger revenue 4,114
    - Freight 583
    - Disbursements[32] 3,372
- Balance -1,438

  of which:
    - Net exports by UK airlines (exports of passenger services and freight, less imports of disbursements 1,458
    - Exports by UK airports (exports of disbursements and other revenue) 1,801
    - Imports by air users (imports of passenger revenue and freight revenue) -4,697

There are other non-market benefits of aviation industry. For example, the availability of frequent and cheaper flights from the UK has enabled the majority of population to visit other countries and maintain international family ties and friendships. Aviation has expanded the choices available to consumers such as seasonal fruits and vegetables that are now available year round.

In order to determine the dependency of the growth sectors in the UK on the aviation industry, a few indicative measures were used:

- An industry's spending on air transport

[31] Revenue generated by airports and other members of the industry.

- Exports as a proportion of output and the degree of foreign ownership (the more international a business, the more reliant it is likely to be on air transportation services)

- The proportion of exports transported by air.

It was demonstrated that the high growth sectors in the UK industry are among the more dependent on aviation services implying that restrictions on the expansion of aviation could constrain overall economic growth of the country.

The aviation industry is very important in the growth of inward and outward foreign direct investment. There is strong evidence that there is a link between the attractiveness of a location for investment and its transport links. According to *Healey & Baker European Cities Monitor 1999*, the top 5 cities for external transport links are also the top 5 cities in which to locate a business.

Air transportation services represent intermediate inputs to the production process of other industries. Cheaper and faster business travel and freight shipments may cause important spillover effects. For example, aviation may contribute to development of the rest of the economy by introducing business innovations that are adopted by other industries—such as British Airways' use of electronic ticketing started adopted by other industries, the use of frequent flyer programs to retain customer loyalty was applied in supermarkets and other retailers, etc.). In addition, "an improved transport infrastructure may lead to a more efficient allocation of resources because of the larger market it creates. This allows greater scope for economies of scale, increased specialization in areas of comparative advantage, and stiffer competitive pressures on companies, encouraging them to become more efficient." (37)

The model used in estimating the economic impacts of aviation provided annual forecasts of output, employment, investment, and prices for 30 sectors of economy. Output for each sector is estimated using a production function. This production function relates the level of output to three key inputs:

1. Employment in the sector
2. Capital equipment available
3. The sector's productivity after taking into account the amount of labor and capital used.

The model further identifies six separate components of air traffic:

1. Leisure passengers: UK residents
2. Leisure passengers: Non-UK residents
3. Business passengers: UK residents
4. Business passengers: Non-UK residents
5. Transfer passengers
6. Freight charges

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[32] Spending on services such as airport charges, accommodations for flight crews, advertising and commission.

While business travel and freight affect other industrial sectors' cost and competitiveness, leisure travel affects tourist spending and has a significant welfare benefits.

It was estimated that an annual reduction of 25 million in the number of passengers would mean that GDP would be £4 billion a year lower by 2015 than if supply were sufficient to meet the projected levels of demand. The capacity to service these 25 million passengers would cost around £1 ½ billion on average. However, the likely impacts of unmet demand for air transportation would probably be greater than the model predicts. This is because if the UK were to lose its reputation as a good place for international business, due to insufficient supply of air transport services, the negative impact of lost investment would affect other sectors of the economy.

Source: The Economic Contribution of Aviation to the UK: Part 2—Assessment of Regional Impact

By: Oxford Economic Forecasting

Date: May 2002

Topics covered: Economic impact of aviation (present and future)

The main purpose of this study is to evaluate and report the contribution of aviation to the regional economies in the UK. The following is a list of main conclusions:

- In 1998, aviation jobs comprised 0.8% (180,000 jobs) of total employment in the UK. In Greater London region alone, the industry provided 2.1% of all jobs.

- In 1998, aviation accounted for 1.4% of GDP in the UK, and 3.2% of London’s GDP.

- Indirect employment in the UK that was supported by aviation was 200,000 jobs for the year 1998.

- “Including ‘induced employment’ supported by the spending of direct and indirect employees, total aviation-related employment in 1998 ranged from 3.6% of all jobs in London and 3.3% in the South East, to 0.9% in Yorkshire & Humberside and in Wales.” (7)

The number of jobs directly provided by aviation industry was constructed from employment studies from individual airports. These studies reported the numbers of employees for each major airport. The number of employees at smaller airports was estimated to be proportional to the number of terminal passengers handled. The national total represents an aggregated total for all airports. However, there are many instances where jobs based at a particular location are sustained by economic activity elsewhere. “There are several specialist centers that service planes that are based at airports in other regions (or indeed overseas).” (11)

Indirect employment takes into account all the jobs supported by the purchases made by the aviation industry. These jobs include “employment in the energy sector associated with purchases of fuel, the aerospace sector, providers of IT equipment, construction workers, and the production of goods sold in the shops in terminal buildings.” (12-13) Several factors affect the ratio of indirect to direct employment: the nature of the business of the direct employer, its sourcing policy, and the degree of vertical integration. Calculations are done for individual airports (as with direct employment) and then aggregated.

Induced employment is created through the spending of the aviation industry's direct and indirect employees. This study estimates that induced employment was 25% of all direct and indirect jobs in the industry. The first step in estimating the induced employment was to establish the region of residence of direct and indirect workers because that is where the majority of spending takes place. However, not all of the spending is done in the region where direct and indirect employees live (i.e., spending on hotels, etc.). For this reason it was assumed that only 50% of induced employment remains in that region while the other 50% is split between all the regions.

The study reports that direct employment in aviation is projected to increase to 210,000 (30,000 increase) by 2015 and to 242,000 by 2030. It is also stated that aviation is expected to generate another 290,000 jobs indirectly (increase of 90,000) by the year 2015. The forecast is based on a few key assumptions. It is assumed that the number of passengers would grow by an average of 2.5% a year between 2015 and 2030; the growth rate would fall to 1.5% a year by the end of the period. It is further assumed that improvement in efficiency of airports and airlines would cause the number of jobs per thousand passengers to fall each year. The productivity growth rate in aviation is assumed to slow to 2% a year by 2020.

Source: Measuring Transportation in the U.S. Economy

By: Xiaoli Han and Bingsong Fang

Publication: Journal of Transportation and Statistics

Date: January 1998

Topics covered: Since it relates to the national transportation as a whole, it is not a good source of information on air transportation industry itself.

This study shows two economic measures of national transportation, one as a component of GDP and the other as a component of gross domestic demand (GDD). It argues that the System of National Accounts (SNA) is the most appropriate framework for comparable economic measures of transportation. Although the study applies to national transportation as a whole, air transportation is also mentioned.

GDP is a sum of consumer expenditures, gross private domestic investment, net exports of goods and services, and government consumption expenditures and gross investment. Personal consumption expenditures included in the transportation function are (page 96):

1. User-operated transportation
   a. New autos
   b. Net purchases of used autos
   c. Other motor vehicles
   d. Tires, tubes, accessories, and other parts
   e. Repair, greasing, washing, parking, storage, rental, and leasing
   f. Gasoline and oil
   g. Bridge, tunnel, ferry, and road tolls
   h. Insurance
2. Purchased local transportation
   a. Mass transit systems
   b. Taxicabs

3. Purchased intercity transportation
    a. Railway
    b. Bus
    c. Airline
    d. Other

Gross private domestic investment is the sum of fixed investment and the change in business inventories. Fixed investment is composed of structures and producers' durable equipment. Transportation and related equipment is comprised of:

1. Trucks, buses, and truck trailers
2. Autos
3. Aircraft
4. Ships and boats
5. Railroad equipment

U.S. exports and imports of transportation services are found in the National Income and Product Accounts (NIPA) tables on U.S. International Transactions and Private Service Transactions under four categories:

1. Passenger fares
2. Freight transportation services
3. Port services
4. Other transportation services

Government consumption, expenditures, and gross investment are classified as relating to highways, water, air, railroads, and transit. Government investment is primarily concentrated on highways and streets. It should be noted that a country's final demand for the products is different from a country's domestic final demand or GDD. "In 1996, U.S. transportation-related final demand was $846.6 billion, while U.S. gross domestic demand for transportation was $888.9 billion, the difference being the net trade of transportation-related goods and services." (97)

Source: Comparing Approaches for Valuing Economic Development Benefits of Transportation Projects

By: Glen Weisbrod and Michael Grovak

Publication: Paper presented at 77th Annual Transportation Research Board Meeting, Washington, DC.

Date: 1998

Topics covered: Measuring benefits of transportation, not related to air transportation
The purpose of this study is to examine and contrast alternative types of economic analysis used in valuing economic development benefits of transportation industries. The alternative types of economic analysis considered in this document are;

1. System efficiency (user benefit) analysis
2. Macro-economic simulation modeling
3. Productivity analysis
4. Strategic planning (scenario) analysis
5. Social welfare (full cost) analysis

Each type of analysis is applied to the economic impact study for Kentucky Highway 69 (KY69) that involved replacing the existing 2-lane road with a 4-lane facility and then discussed in terms of measures, analysis, results, and issues. Considering that the focus of the study is measuring investment in a highway project, the results of each analysis type are not relevant to the purpose of this literature review and will not be reported.

System Efficiency Analysis—System efficiency or user benefit analysis measures benefits in terms of travel time, travel expenses, and safety for travelers. The analysis distinguished between trucks and automobile trips and between work and non-work trips. It was proposed that: there would be a 3% shortening of the highway length which would reduce travel time and cost; there would be an increase in average speed that would reduce travel time but increase vehicle operating cost; some travelers from other roads would prefer to use the improved highway in order to reduce travel time but this benefit would be offset by an increase in distance and operating costs. "The advantage of this type of analysis is that it is straightforward. The disadvantage is that it values only direct benefits to highway system users, and the level of those benefits reflect only a limited set of factors—direct cost, traveler time and accident cost." (5)

Macro-Economic Simulation Modeling—Regional macro-economic simulation model measures benefits in terms of cost savings and other productivity benefits. It measures impacts in terms of effects on employment, income, and value added (GDP). One of its advantages is that it reflects the benefits of projects to non-users. This study used the Regional Economic Models, Inc. (REMI) simulation model. The first step focused on defining the following model inputs:

- Safety benefits: Only affect incomes insofar as they affect insurance rates, hospital staffing, and attractiveness of location in the region.

- Operating cost: In this case direct operating cost savings for trucks translate to real cost savings for business. However, due to lower fuel economy at higher speeds there are negative overall cost savings that represent a loss of disposable income for residents, although gas station sales do increase.

- Travel time: The time savings for trucks and work trips are real cost savings for businesses. The portion of car travel time savings associated with commuting to or from work only affect businesses if employee work hours are affected. For non-work trips, time savings translates into quality of life benefit without affecting the flow of income and spending (though it increases attractiveness of the area and therefore the income in the long-term).

The second step was to allocate the benefits to existing businesses located within the study area or elsewhere in Kentucky. "The allocation of business cost benefits was calculates as follows: For each sector, we define $A_s = B_s * C_s * D_s$. A_s is $ of total business activity accruing to sector '$_s$'; B_s is total $ of business activity in sector '$_s$'; C_s is percent of business activity in sector '$_s$' spent on highway-related costs; and D_s is percent of total highway travel by sector '$_s$' that can benefit from KY 69 improvement." (7)

The third step is the estimation of additional impact on attraction of tourism and business activity resulting from economic efficiency and productivity benefits. The following are techniques used in completing this step:

- Market estimation models

- Interviews of businesses, economic development and tourism professionals

- Survey of business expectations

The advantage of macro-economic simulation modeling is that it accounts for transportation effects of cost savings, productivity enhancement, and market growth and their effects on business expansion, competitiveness, etc. A limitation of this approach is that it only takes into account the effects on private sector business income and consumer income without placing value on social, environmental and quality of life benefits.

Productivity Analysis—Productivity analysis measures the impacts of investment in terms of net business costs, business output, productivity (cost/output ratio), or willingness to pay for additional highway spending benefits. "An advantage of this approach is that it yields estimates of overall impacts on various types of business, which encompass all of the effects of logistics and market scale economies that were crudely estimated on a project-specific basis for the economic simulation modeling (previously discussed). A major limitation of this approach is that it utilizes historical data to calibrate models relating productivity increases to levels of highway inventory rather than actual accessibility improvements." (11)

Strategic Planning (Scenario) Analysis—Scenario analysis relies on macro-economic modeling to represent the jobs, income and output impacts of transportation improvements. Therefore, all the limitations associated with macro-economic modeling are carried over to scenario analysis. Its advantage is that it identifies upside possibilities and downside risks affecting the economic impacts of transportation projects.

Social Welfare Analysis—Social welfare analysis assesses all impacts of transportation projects on users, non-users, environment, and society. Social welfare includes such factors as the full value of time, cost, and safety for travelers, the additional value of productivity changes for business and employees, and the value of environmental quality changes for residents and users of affected area. One of the limitations of this approach is the difficulty and lack of consensus on the appropriate valuation of non-economic effects.

The appropriate type of analysis depends on the purpose of the transportation project, the intended use of the analysis results, and the scale of the impact to be studied. System efficiency modeling of travel impacts is more commonly used though it ignores some elements of business efficiency and quality of life factors that are captured by macro-economic modeling and social welfare analysis. Macro-economic modeling is most appropriate for large-scale projects with significant economic impacts.

Source: Economic Development Impact of Airports: A Cross Sectional Analysis of Consumer Surplus

Publication: Transportation Research Record 1274

By: Bahar B. Norris and Richard Golaszewski

Date: 1990

Topics covered: Economic Impacts of Aviation. Measuring the benefits of aviation infrastructure

In this study the economic impact of an airport are measured using consumer surplus. The impact of an airport is divided into two parts:

1. The impact from the purchases of air transportation services, and

2. The consumer surplus from a decline in prices of air transportation following the construction of the facility.

The size of the airport purchase impact is related to the diversity of the regional economy while the size of consumer surplus depends on the accessibility of the region, the industrial mix of the region, and the importance consumers attach to continuing operations of the airport.

A cross sectional analysis was conducted on two airports. One airport was located on an island economy without many alternate means of transportation and the other airport was in Dallas Fort Worth (DFW) area where numerous transportation alternatives and other airports are available. In order to determine the economic impacts of the two airports, two survey types were conducted. "The first type of survey measured the transportation purchase impact of the airports by measuring the final demand impact of the airport generated as a result of the purchase of air transportation services; whereas the second type measured the economic development impact by estimating the consumer surplus of the non-aviation firms in the region" (84).

The final demand impact of air transportation purchase was estimated by collecting data from all on-airport firms and a sample of off-airport firms. On-airport firms included:

- Passenger airlines
- Cargo airlines
- Airline suppliers
- Airport concessions, and
- Airport board and government agencies.

Off-airport firms that were sampled included:

- Hotels
- Travel agencies
- Airline headquarters and ticket offices
- Car rentals, and
- Ground transportation agencies.

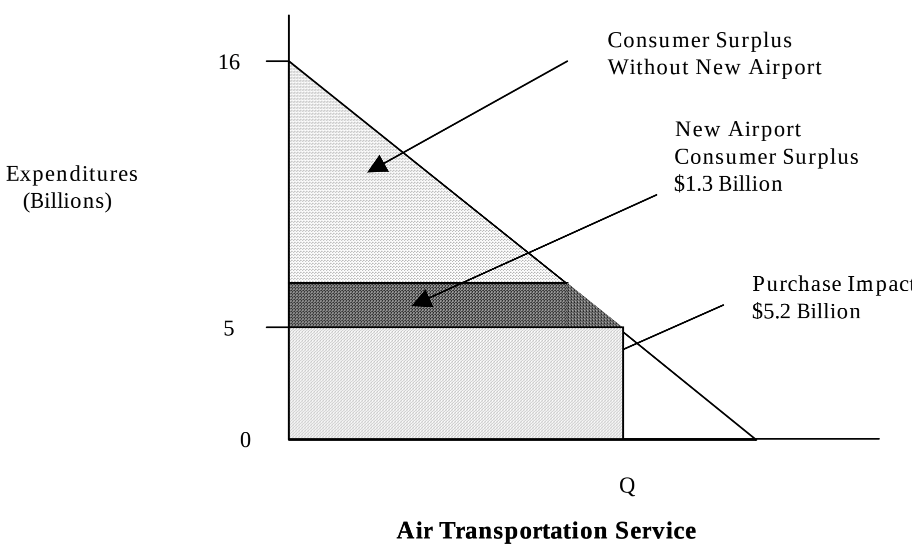

Figure 1: Air Transportation Impact for DFW Airport (85)

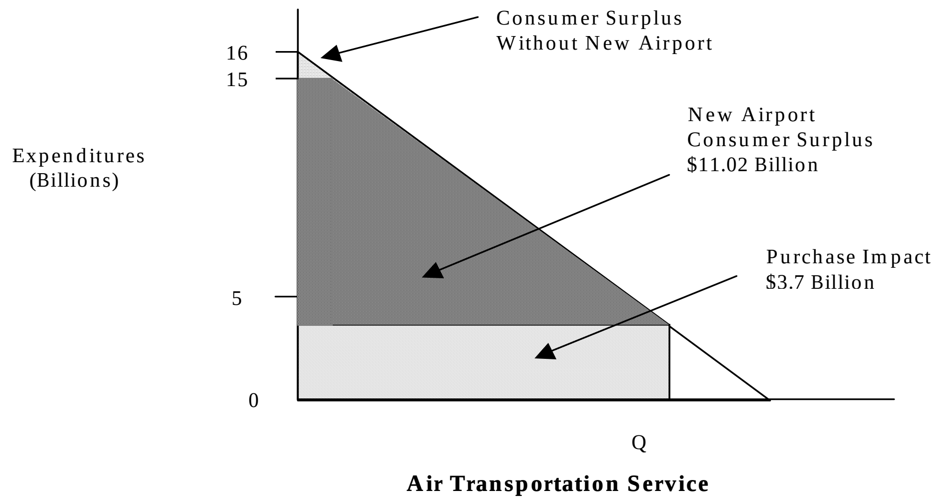

Figure 2: Air Transportation Impact for Island Airport (85)

Figures 1 and 2 show the transportation purchase impact in relation to the consumer surplus income for the DFW airport and for the island economy. For the DFW region," … both the absolute and relative size of the transportation purchase impact were larger when compared with the island economy ($5.26 billion compared to island's $3.73 billion for total impact; and $1,571 per capita compared to the island's $612 for per capita impact). In the same economies, because of the differences in accessibility and industrial mix characteristics, the relative magnitudes of the consumer surplus were reversed. The DFW region showed a relatively small economic development impact ($1.3 billion, or one-fourth of the purchase impact), whereas the island economy showed a relatively large impact ($11.03 billion) that was three times larger than the purchase impact. (82)

The overall purchase impact is composed of primary and secondary impacts. National Income Accounting was the method used in estimating the primary demand impact composed of the first round of expenditures attributed to the airport. The secondary impacts composed if the induced-multiplier effect impacts and indirect impacts were estimated using the input-output multipliers and RIMS II model generated by the Bureau of Economic Analysis.

Consumer surplus was used as a measure of economic development income. It was estimated using a combination of survey methods and econometric models. The sample firms surveyed were asked to estimate their dependency on the airport. A regression model was used to assess the magnitude of the development impact and the firms' degree of airport dependency. It was concluded that in the DFW region, each resident was willing to pay an additional $371 rather than go without the airport while in the island economy each resident was willing to pay as much as $1,807.

The study led to a few interesting findings. The difference in size of the consumer surplus in the DFW region and in the island economy suggests that the degree of airport dependency and consumer benefits is positively related to the supply constraints. In both regions, the operations of the airports contributed to economic growth. The size of the consumer surplus and airport dependency is influenced by the availability of substitute transportation models and competing airports: The relative size of the consumer surplus in DFW region is small because of the existence of other transportation modes and other airports. Firms producing products with high price elasticity have the highest degree of airport dependency.

Source: The Economic Benefits of Air Transportation

Publication: The Air Transport Action Group (ATAG)

Date: 2000

Topics covered: Economic Impacts of Aviation. What do studies say about current impact on US economy?

The importance of air transportation industry in world economic activity is immense. According to this study, more than 1,600 million passengers annually rely on travel by air and approximately 40% of the world's manufactured exports are transported by air. The increase in demand for air transportation causes airport congestion and unless governments and other authorities invest in aviation infrastructure, future economic growth will be jeopardized.

In order to assess the economic benefits of air transportation, it is necessary that direct, indirect, and induced impacts be taken into consideration. As in the previous studies, the direct economic impact represents the activities of airlines, airports, and businesses located at airports. The indirect economic impact comes from off-airport activity of passengers and shippers (i.e., hotels, restaurants, travel agencies, etc.). The induced impact uses a multiplier effect to estimate the successive rounds of spending generated by the economic activities of the recipients of the direct and indirect economic benefits.

The following are some economic impacts of aviation (13):

- The total economic impact of aviation on world output in 1998 was $1,360 billion (direct impact: $320 billion; indirect impact: $390 billion; and induced impact: $650 billion).
- The total economic impact of aviation on the labor market is estimated at 28 million jobs (Direct impact: 4 million; indirect impact: 8 million; induced impact: 15 million people).
- Aviation generates taxes: in the United States alone, the federal user taxes and fees paid by airlines are more than $9.2 billion. In addition, airline employees in the US paid over $2.2 billion in payroll taxes.
- Commercial aviation reduces the cost of doing business and attracts new businesses to locations with air service.

The economic benefits can only be fully realized if air transport is able to meet the demand for its services. Therefore, it is important not to allow the congestion increase to continue without attempting to curb it. "In the US, air traffic control delays are conservatively estimated by the ATA to have cost airlines and their costumers more than US$4.5 billion in 1998, with a 10% increase in cost forecast for 1999" (26).

Source: Economic Impact of Civil Aviation on the U.S. Economy

Publication: Wilbur Smith Associates with Applied Management Solutions, Inc.

Date: March 2000

Topics covered: Economic Impacts of Aviation. What do studies say about current impact on US economy?

The purpose of this study is to assess the impacts of civil aviation on the U.S. economy. In this study, the economic impact of aviation is measured in terms of economic activity, earnings, and jobs and is reported in 1998 dollars. "'Economic Activity' is the value of the aviation final demand (aircraft, aviation services), plus the sum of all of the intermediate goods and services needed to produce the aviation final demand, plus the induced impacts of increased household consumption." (2) Economic activity impacts of civil aviation were estimated to be $975.7 billion. The direct/indirect impacts of $339.6 billion yield an additional $636.0 billion in additional economic activity. Earnings are the sum of all wages and salaries paid by aviation industry directly, indirectly or through the induced impacts. Earnings were estimated to be $278.4 billion. The jobs attributed to the aviation industry equal the number of employees in aviation industry and the aviation-oriented share in other industries. It was estimated that 10.9 million jobs exist due to the aviation industry.

In order to measure aviation's contribution to GDP, the impact measure must only include the value added components. The model used in this study is RIMS-II input/output model. The wages, salaries, other labor income, and proprietors' income amount to 69% of total GDP. "To estimate aviation's total contribution to GDP, this same 69% was applied to total earnings. This yields the estimated total value added impact of aviation on the U.S. economy. … Aviation's contribution to GDP is 4.7%, which includes aviation provision, use, and induced impacts but excludes the benefits accruing to American business from the ability to use aviation." (6)

Commercial aviation in the United States includes:

- 402 airports with scheduled airline service
- 145 with unscheduled service
- Over 60 air carriers
- Over 20 all-cargo air carriers
- Over 100 regional/commuter airlines
- 660 million annual passenger enplanements
- Over 32,700 travel agency locations
- Over 12,800 satellite ticket printers
- Hotels
- Rental car agencies
- Other firms serving air passengers

"Commercial aviation-related economic activity totals $911.2 billion annually, including 10.3 million employees who earn $258.5 billion annually. … Overall, 'commercial aviation's' impact is estimated to comprise 93.4% of aviation's total impact (general aviation comprises the remainder)." (9)

General aviation is a significant U.S. industry. There are 547 airports with commercial service certificate (also used by general aviation) and 18,199 airports for general aviation use only. Further, general aviation had over 87 million aircraft operations in 1998. Due to the large volume of general aviation activity, general aviation's impacts in the U.S. economy are substantial. Economic activity caused by general aviation is estimated to equal $64.5 billion annually. General aviation and related activity employs 638,000 people who earn $19.9 billion.

The importance of the aircraft manufacturing impact on the U.S. economy cannot be ignored. "In 1998 the civil aircraft industry comprised 19 aircraft assembly firms and over 10,000 other firms that build engines, subassemblies, components, and parts. … The industry in 1998 had net non-military sales of $41.4 billion." (12) These funds were traced through the economy and it was found that their impacts on the economy were:

- $126.9 billion in annual economic activity
- $37.6 billion annual earnings
- Over 1.0 million jobs in the United States

The study states that the economic impact of aviation continues to increase even when aircraft manufacturing or general aviation activity decline because aviation use continues to increase.

Source: A Note on the Use of Port Economic Impact Studies for the Evaluation of Large Scale Port Projects

By: A. Verbeke and K. Debisschop

Publication: International Journal of Transportation Economics, Vol. 23 No. 3

Date: October 1996

Topics covered: Using economic impact studies

This article is a critical evaluation of the usefulness of port economic impact studies in the public decision making process. When assessing the future impacts of an investment in transportation infrastructure, it is important not to confuse wealth distribution and wealth generation. While the wealth distribution is simply a shift of wealth it does not increase the net economic wealth.

The economic impact of a project could be calculated by estimating the project's net contribution to economic welfare. "The economic welfare resulting from each project or programme is thus seen as its sustainable contribution to the total value added created in the relevant geographic area, i.e., the GDP in the case of a nation or gross regional product in the case of a region" (253).

One of the main points of criticism of port economic impact studies is that "an impact study cannot adequately deal with marginal changes in the pricing of inputs and outputs as compared to a social cost-benefit analysis. … However, an impact study should always be performed for the situation 'with the project' as compared to the situation 'without the project.' From this perspective, a marginal analysis is obviously undertaken." (254-255)

A second major criticism refers to the fact that wages, depreciation, and financial costs are viewed as benefits in an impact analysis while they are treated as costs in a social cost-benefit analysis. In regards to this argument it is important to note the importance of the concept of sustainability. That is to say, impact studies discard all the components that are not sustainable so for example, wages paid to the workers working on a construction of the project are not included because they are not sustainable. Commercial or industrial activities that have a negative or very low profitability are also considered unsustainable.

It is difficult to make a decision about a project approval based on an economic impact study as opposed to using a cost-benefit study where all projects with a NPV>0 could be carried out and a project with NPV<0 could be automatically rejected. While there is no general rule on when to accept or reject projects based on an economic impact study, it is possible to rank projects in function of their expected contribution to value added per invested monetary unit.

"A forth element of criticism, related to the use of impact studies, is the normative point of view that government should not stimulate value added and employment in the economy through transport infrastructure, e.g. in seaports, but through more direct measures such as the reduction of taxes or the subsidization or commercial and industrial activities." (256-257) This may be true from a welfare economics point of view. However, it is often not the case in the real world where budgetary issues cane make it difficult to decrease taxes or increase direct subsidies.

Since economic impact studies measure the economic impact of a project as a sum of direct, indirect, and induced impacts, they are often criticized as possibly biased when assessing indirect and induced impacts. However, a correct assessment should be based on reliable data and evidence in order to avoid uncertainty about the validity of an economic impact study finding.

It is also argued that impact studies do not allow the use of shadow prices for valuation, producing a distorted picture of the real effects of a project from a perspective of economic efficiency. It is true that impact studies have limitations and therefore should be used in conjunction with other evaluation tools.

Source: Transportation Investment and Economic Development: Is there a Link?

By: Joseph Berechman

Publication: European Conference of Ministers of Transport, Round Table 119

Date: 2002

Topics covered: Measuring Benefits of Investment in Transportation Infrastructure

In this study, transportation investment is a capacity improvement or addition to an existing network of roads, rail, waterways, hub terminals, tunnels, bridges, airports, and harbors. The economic growth that results from a transportation investment is considered to mean the long-run increase in economic activity in a given area. "[T]he main argument regarding economic growth ensuing from transportation infrastructure development is that the mechanism which transforms accessibility benefits into economic growth benefits is the presence of allocative externalities in specific markets, which are amenable to improved accessibility. The scale, spatial and temporal distribution of these externalities will affect the magnitude and scope of economic growth, given the transportation investment." (116)

Some of allocative externalities are labor market economies, economies of industrial agglomeration, transportation market economies, and environmental externalities. Transportation improvements can potentially increase the labor participation especially in low income areas where poor accessibility is one of the main entry costs into the labor force. Economies of industrial agglomeration arise when benefits to firms accrue due to their proximity to other firms (i.e., due to the presence of local public goods, common local pool of skilled labor, etc.). Transportation market economies arise when "a new link to the in-place network can result in increased traffic flow over the entire network that is *larger* than the additional traffic over the new facility.

The author reviewed three more common modes of measuring the impacts of capital investment projects on economic growth: the macroeconomic production function, cost benefit analysis models, and microeconomic models. Macroeconomic models mostly measure aggregate output as a function of: technology, labor, private capital, and public capital. One of the problems with using this model in assessing the economic impacts of transportation investments, is that "the model does not demonstrate causality, rather it presupposes it," (121) meaning that an increase in investment and economic growth could simply be correlated.

The cost benefit analysis approach is the most often used in assessing the present value of the future benefits relative to the project's costs. When considering the success of this type of analysis in correctly assessing the benefits from infrastructure projects, the author stated "[t]he majority of studies on this subject have concluded that the *ex post* demand level is at least 50 per cent below their *ex ante* estimated demand, and that the *ex post* costs of new transportation systems, on the average, are 50 per cent more than their *ex ante* estimates." (124)

Microeconomic models precisely define the link between improved accessibility and economic growth. The key measures of growth used in microeconomic modeling are: firm-related, individual or household related, technology-related and market-related. Firm-related growth measures are changes in output/input ratio, changes in partial and full factor productivity, changes in the amount of input factors employed, changes in the firm's technical and cost efficiency, and changes in agglomeration. "Individual or household-related measures of economic growth are those which entail increases in individuals' utility relative to their consumption and opportunity space." (124) Technology-related measures reflect the increases in the use of technology following infrastructure improvements. Market-related measures are a combination of the above measures and include: the level of equilibrium employment, income per capita, the number of new firms, etc.

Finally, the author urges for more *ex post* type studies of transportation investment projects in order to corroborate or dispute the economic growth and other benefits from transportation investment.

APPENDIX G. Biographical Summaries

Dr. John A. Cavolowsky, team co-lead. NASA (1989-present). Assistant Program Director, NASA Airspace Systems Program, (2000-present). Technical Manager for Aerospace Programs and Special Assistant for Management Support, Office of the Center Director (1997 –2000). Technical chair for the goals assessment panel sessions and future directions workshops of the Turning Goals Into Reality (TGIR) Conference, NASA Headquarters (2000). Ph.D., M.S., S.B., in mechanical engineering.

Lee A. Olson, team co-lead. FAA (1992-present). Senior Staff Engineer, FAA Office of Aviation Research, (1995-present). Permanent staff, co-lead for infrastructure, Commission on the Future of the United States Aerospace Industry (2001-2002). Core staff, Air Transportation Advisory Group (2001). Core staff, Federal Transportation Advisory Group (Vision 2050 report) (2000-2001). Program management, air traffic control system acquisitions, FAA (1992-1995) and Department of Defense (1988-1992). MBA; B.S. in mechanical engineering.

Team Members In Alphabetical Order

B. David Ballard. Senior economist, GRA, Inc. (1996-present). Participated in studies of diverse aviation and aeronautics issues including aviation safety, aeronautics research and development, benefits and costs of regulation, and aviation forecasting; Economic analyst, Office of Thrift Supervision and Federal Home Loan Bank of Dallas (1988-1990). Member of the Aviation Economics and Forecasting Subcommittee of the Transportation Research Board. M.S. in economics; M.S. in mathematics; B.S. in economics and mathematics.

Patricia E. Carroll. Project Management Specialist, Orbital Sciences Corporation (2002-present) supporting NASA's Airspace Systems Program Office. More than 20 years experience writing, producing, and managing scientific and technical editorial projects for NASA and industry, including the NASA Advanced Supercomputing Division (formerly the Numerical Aerodynamic Simulation [NAS] Systems Division (1989-92) and the Space Projects Division (1996-97) at NASA Ames Research Center. A.B. in communication.

Richard Golaszewski. Executive Vice President, GRA, Inc. Specialist in aviation economics, public policy, and safety. Conducted studies of airports, airlines, aircraft manufacturing and aviation infrastructure. Directed major studies including: appropriate role of government in civil aeronautics research, international competition in civil aircraft manufacturing, and domestic and international aviation policy. Member of Aeronautics and Space Engineering Board of National Research Council, Aviation Economics and Forecasting Committee of Transportation Research Board, and Public Policy Committee of American Institute of Aeronautics and Astronautics. MPA; B.S. in accounting.

Shahab Hasan, Program Manager and Research Fellow, Logistics Management Institute (2001-present); Benefits and Safety Assessments Manager, Advanced Air Transportation Technologies Project Office, NASA Ames Research Center (2000-2001). Modeling and Simulation Manager, Advanced Air Transportation Technologies Project Office, NASA Ames Research Center

(1999-2000). Aerospace Engineer, Systems Analysis Branch, NASA Ames Research Center (1993-1999). M.S. in mechanical engineering; B.S. in aerospace engineering.

Dr. James L. Poage. John A. Volpe National Transportation Systems Center, Research and Special Projects Administration, U.S. Department of Transportation. Works in the areas of performance measures, project portfolio decision-making and management, programmatic risk assessment, and knowledge work business processes. Recent applications focused on NASA and FAA aviation research and development programs. Ph.D. in applied mathematics; B.S. and M.S. in electrical engineering.

George Price, Special Assistant, Office of Aerospace Technology, NASA Headquarters (2002-present). Deputy Program Manager, NASA Rotorcraft Program (2000-2002). Senior technology management and strategic planning positions with Sikorsky Aircraft Corporation (1963-1999). Member of numerous industry and government advisory committees. B-52 maintenance officer, U.S. Air Force (1959-1962). M.S. in operations research; B.S. in aeronautical engineering.

Mark A. Safford, Management and Program Analyst, Transportation Strategic Planning and Program Development Office, John A. Volpe National Transportation Systems Center, Research and Special Programs Administration, U.S. Department of Transportation (1990-present). U.S. Department of State (1979-1990). Naval Air Systems Command, U.S. Department of the Navy (1978-79). B.A. in history; M.A. in English history; M.P.A.

Roger D. Schaufele, Jr., Industry economist, FAA Office of Aviation Policy and Plans, (2000-present). Manager, System Forecasts US Airways (1992-2000). Market and strategic planning positions with McDonnell Douglas Corporation (1984-1992). B.A. and M.A. in economics.

Earl R. Wingrove III, Research Fellow, Technology Assessment and Resource Allocation Group, Logistics Management Institute (1991-present). Project Leader for team of economists and airline industry experts that generated long-range forecasts of air transportation demand (2002 - 2003). Supported NASA through creation of economic and other models to analyze the air transportation industry and development of relevant information databases (1993 - 1998). Army officer, Department of Defense (1978-1991). MBA, MPA, B.S. in general engineering.